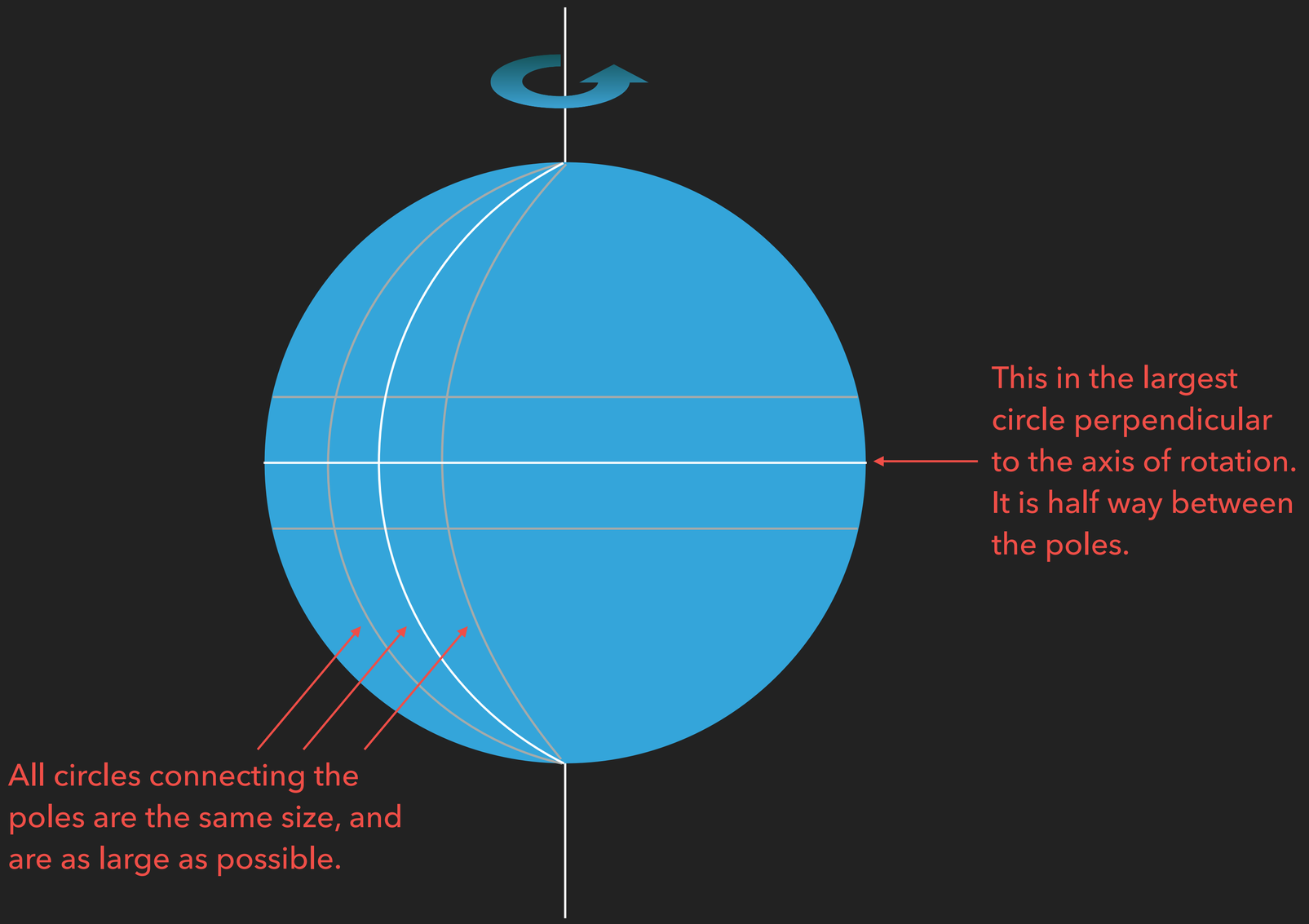
THE ECLIPTIC

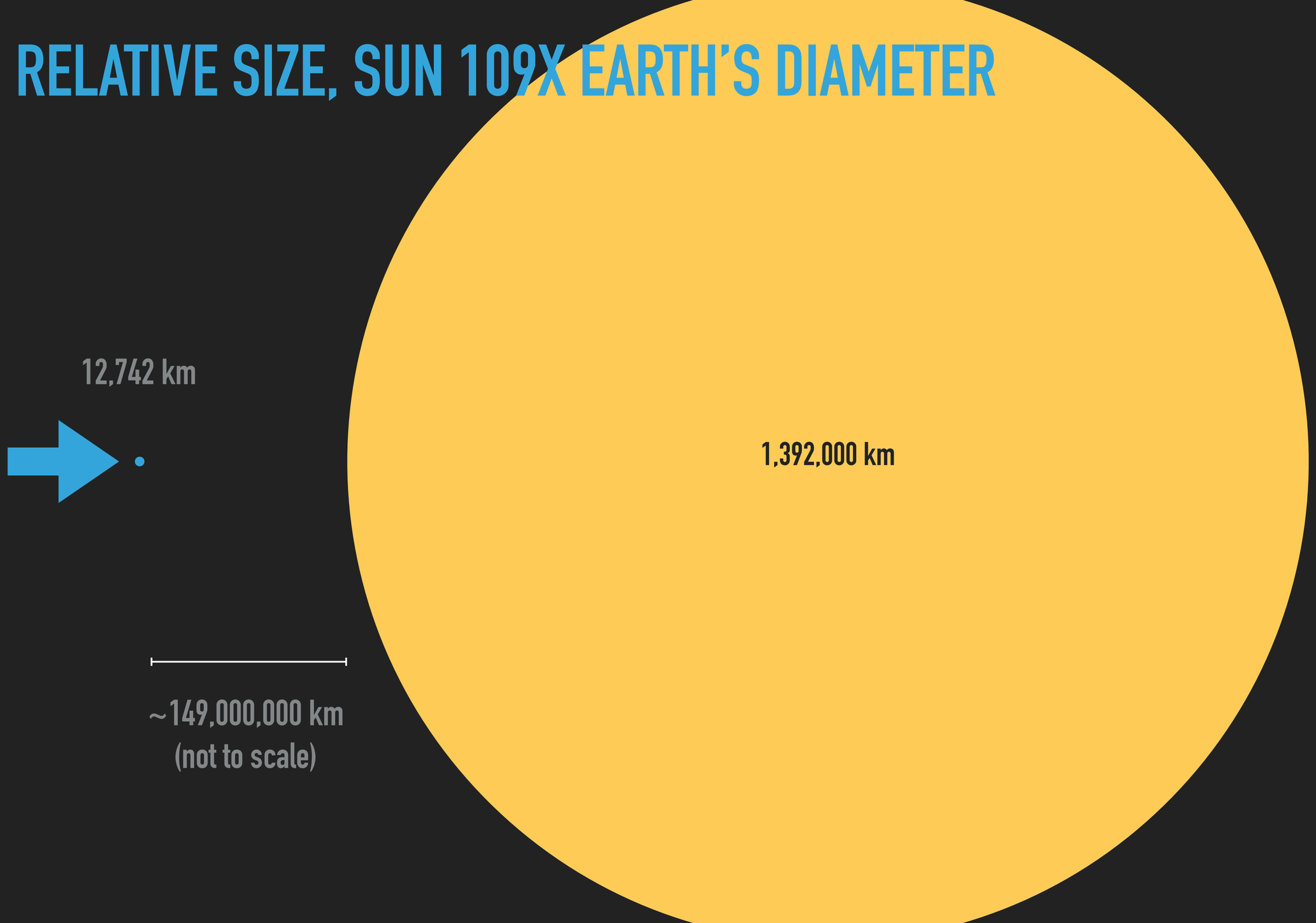
SPACE

A SPHERE IN SPACE

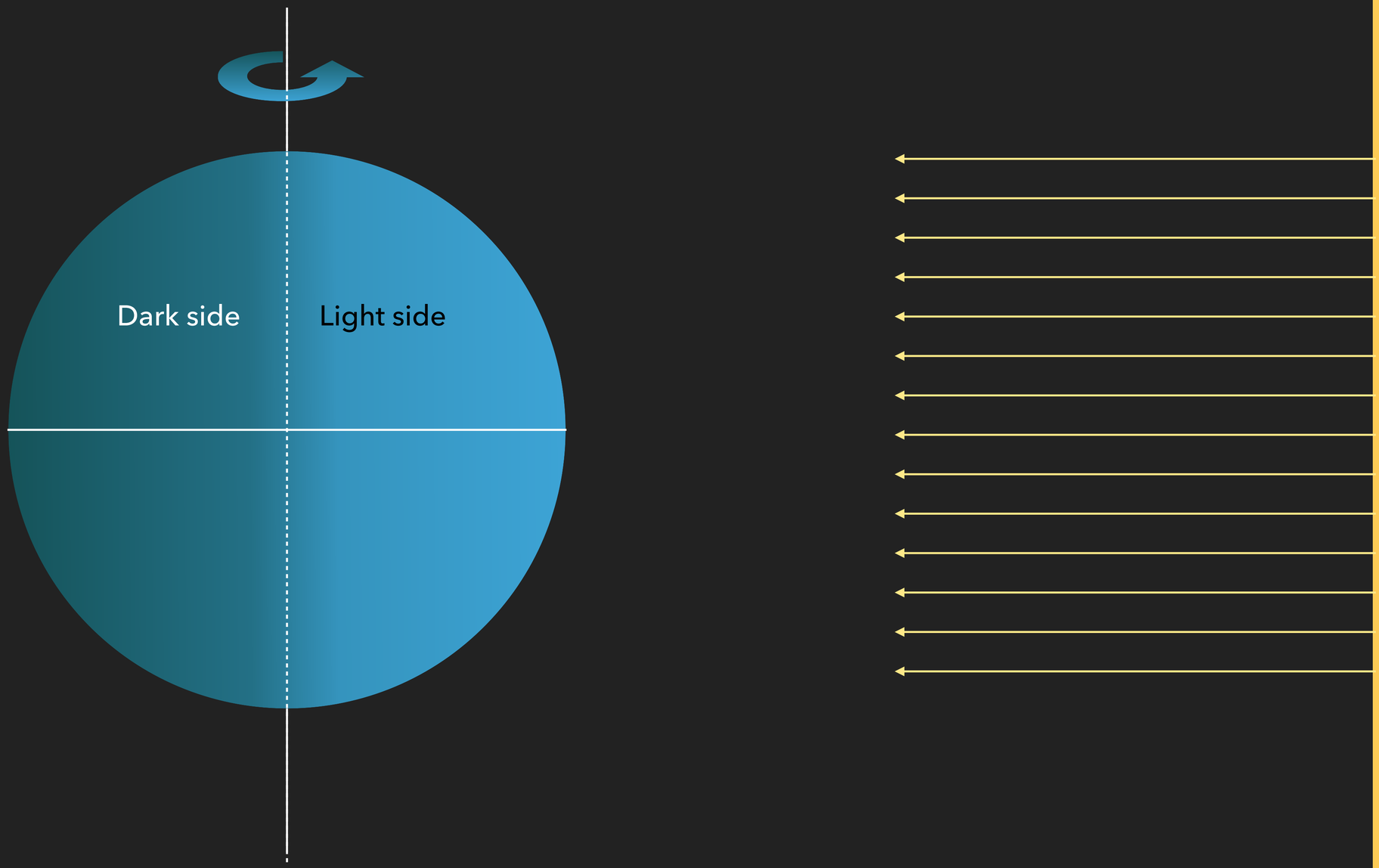
A SPHERE IN SPACE, SPINNING



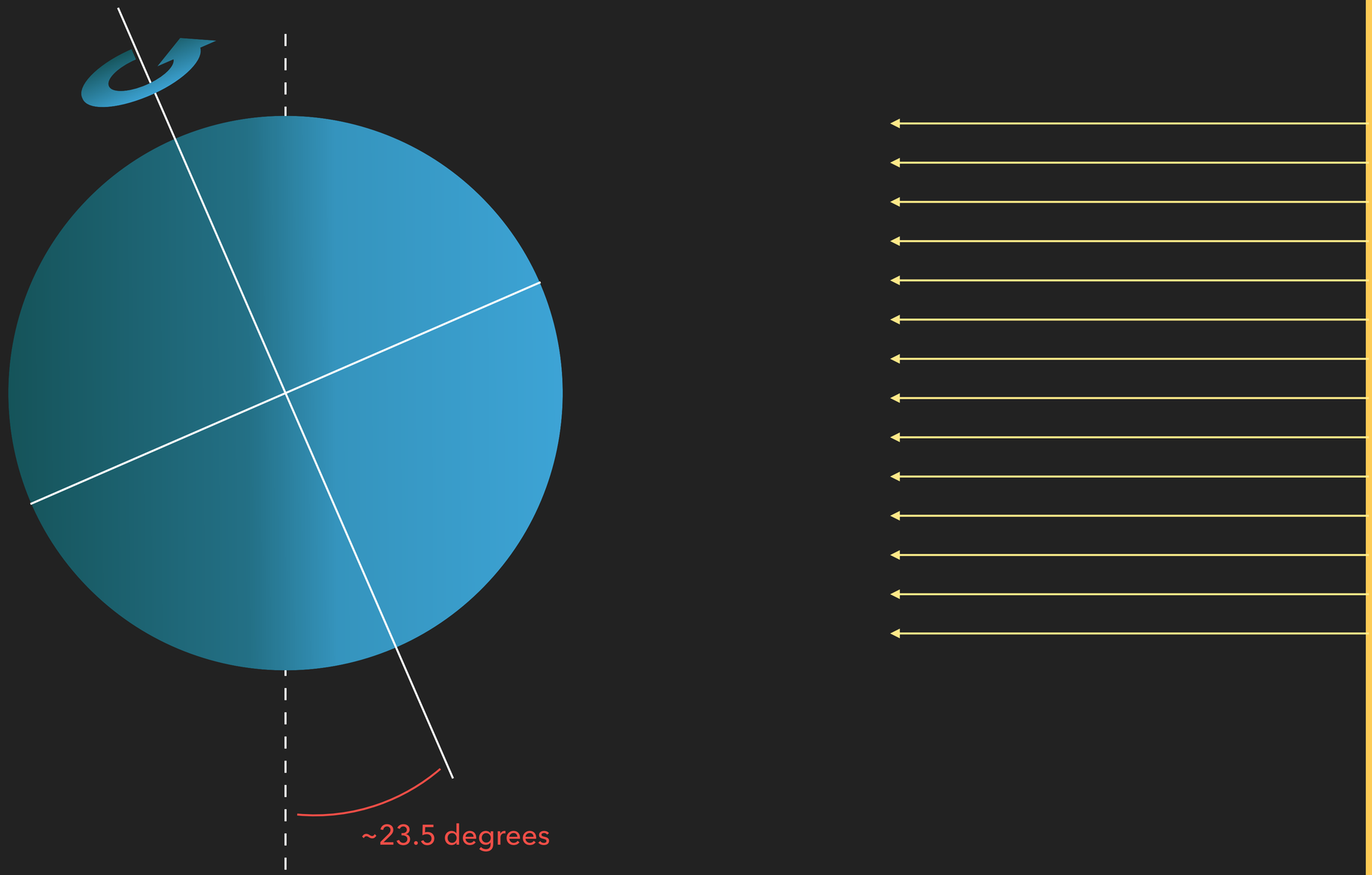
RELATIVE SIZE, SUN 109X EARTH'S DIAMETER



RELATIVE DISTANCE, EARTH NOT VISIBLE

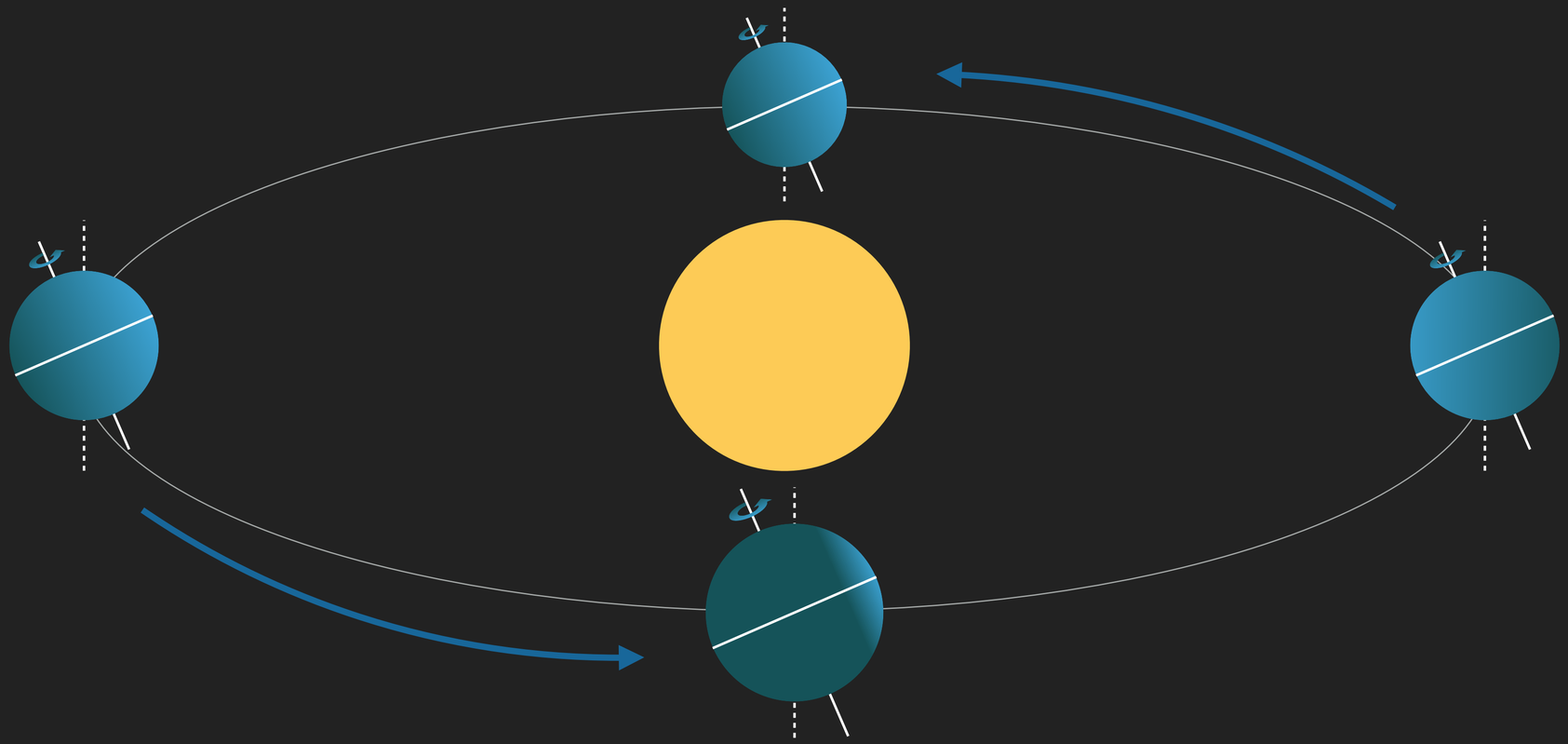

Dark side
Light side

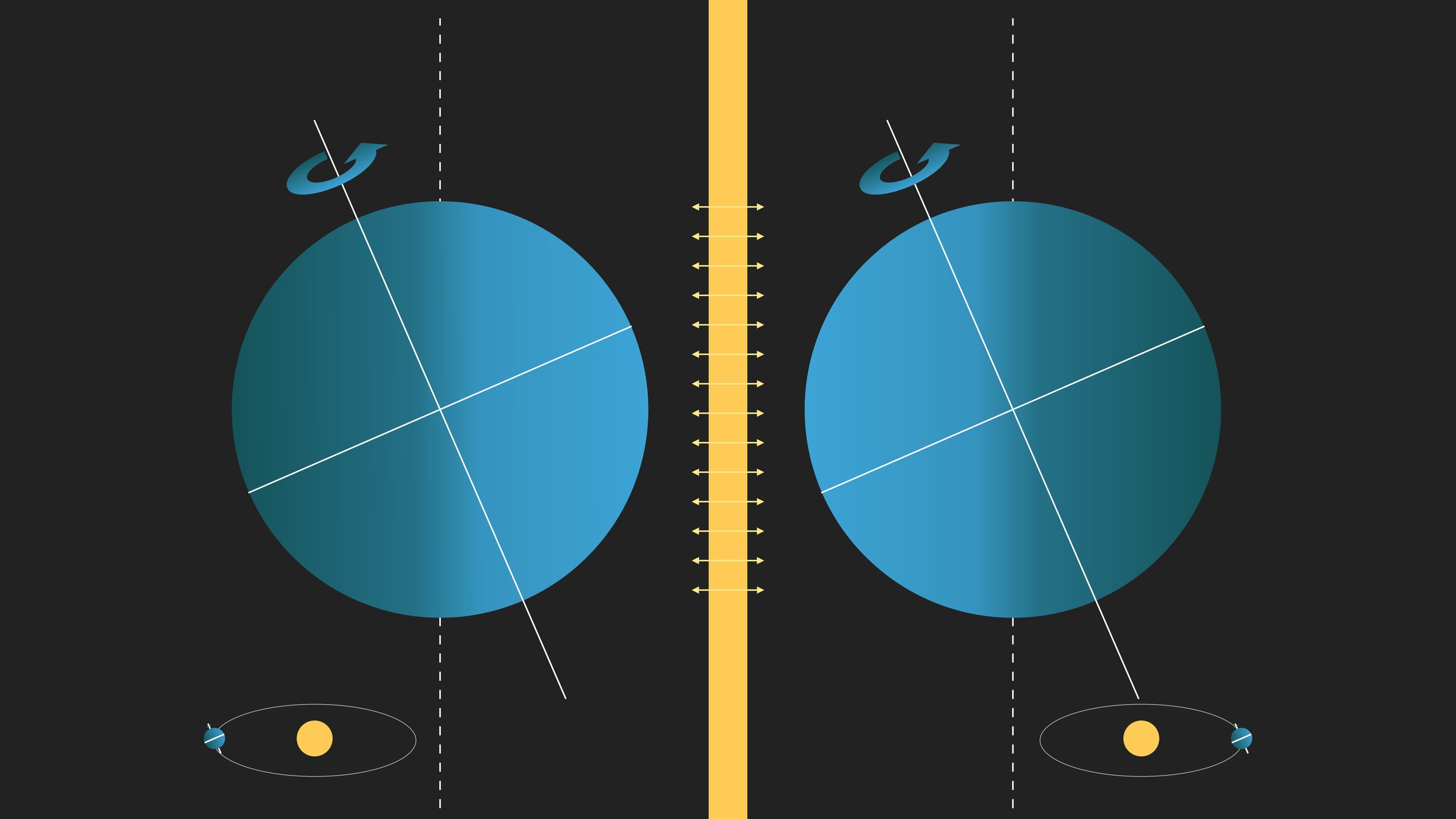
A SPHERE IN SPACE, SPINNING, TILTED

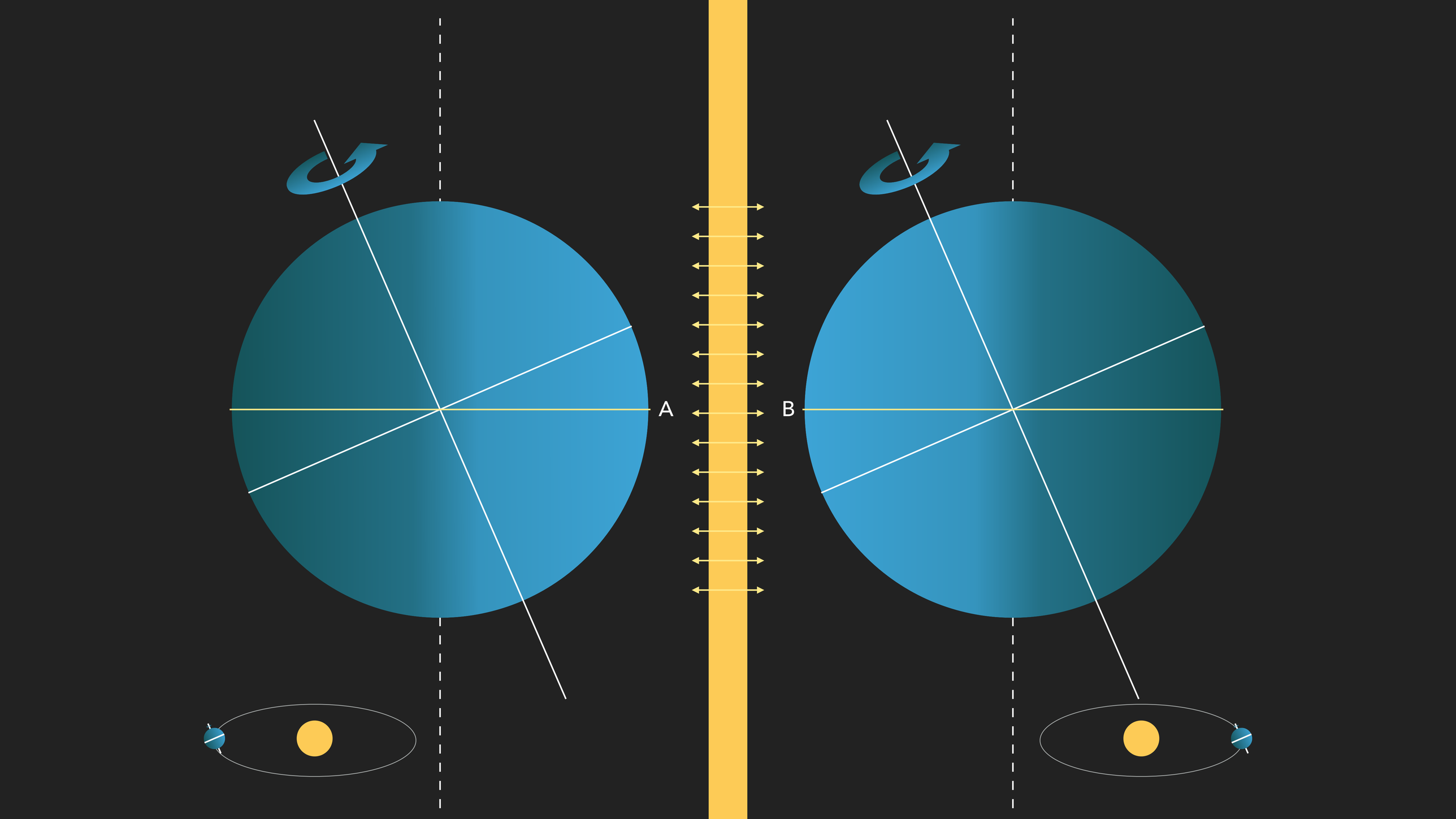


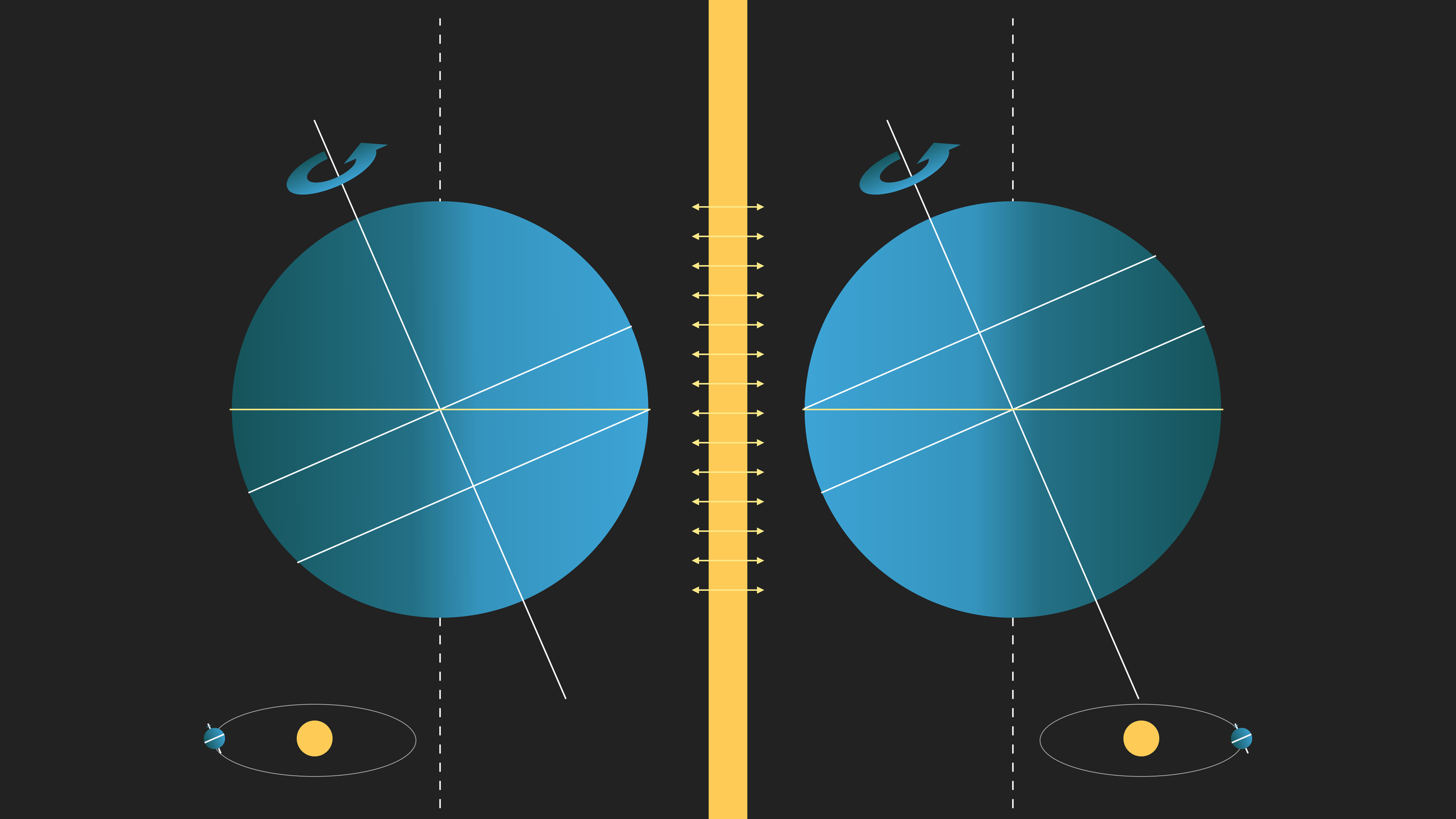
A SPHERE SPINNING, TILTED, AND ORBITING

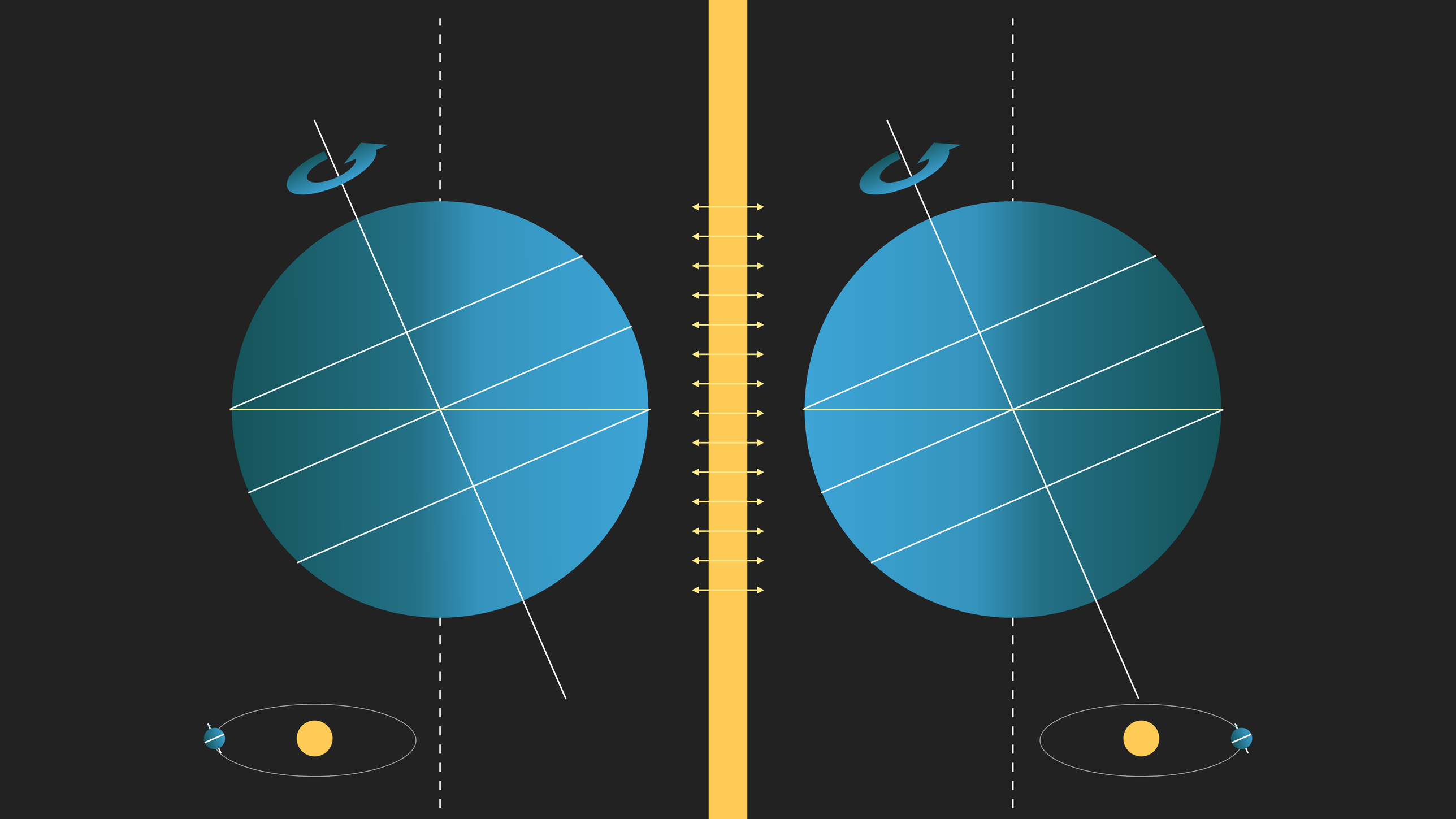
WITH CONSTANT TILT

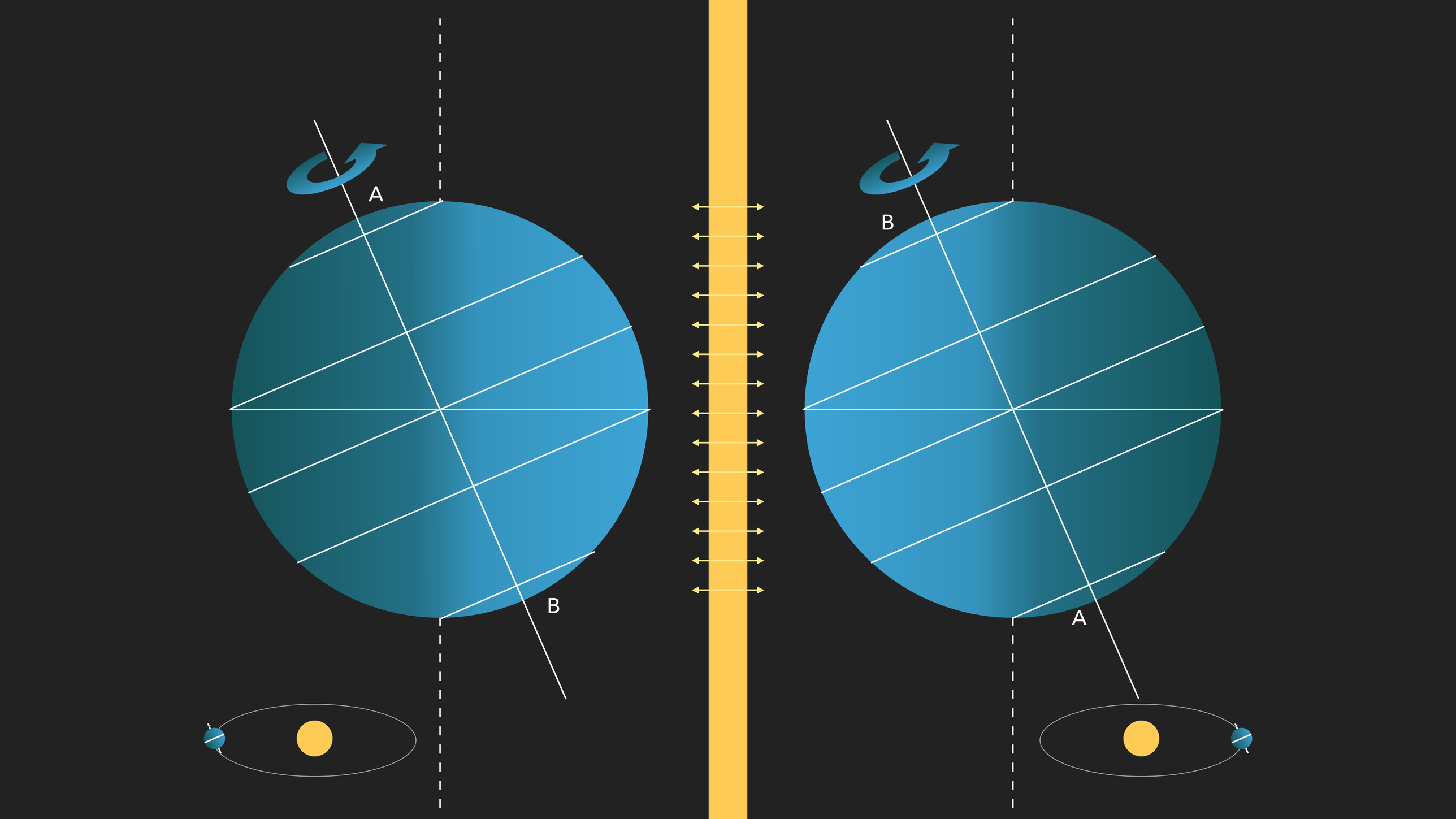


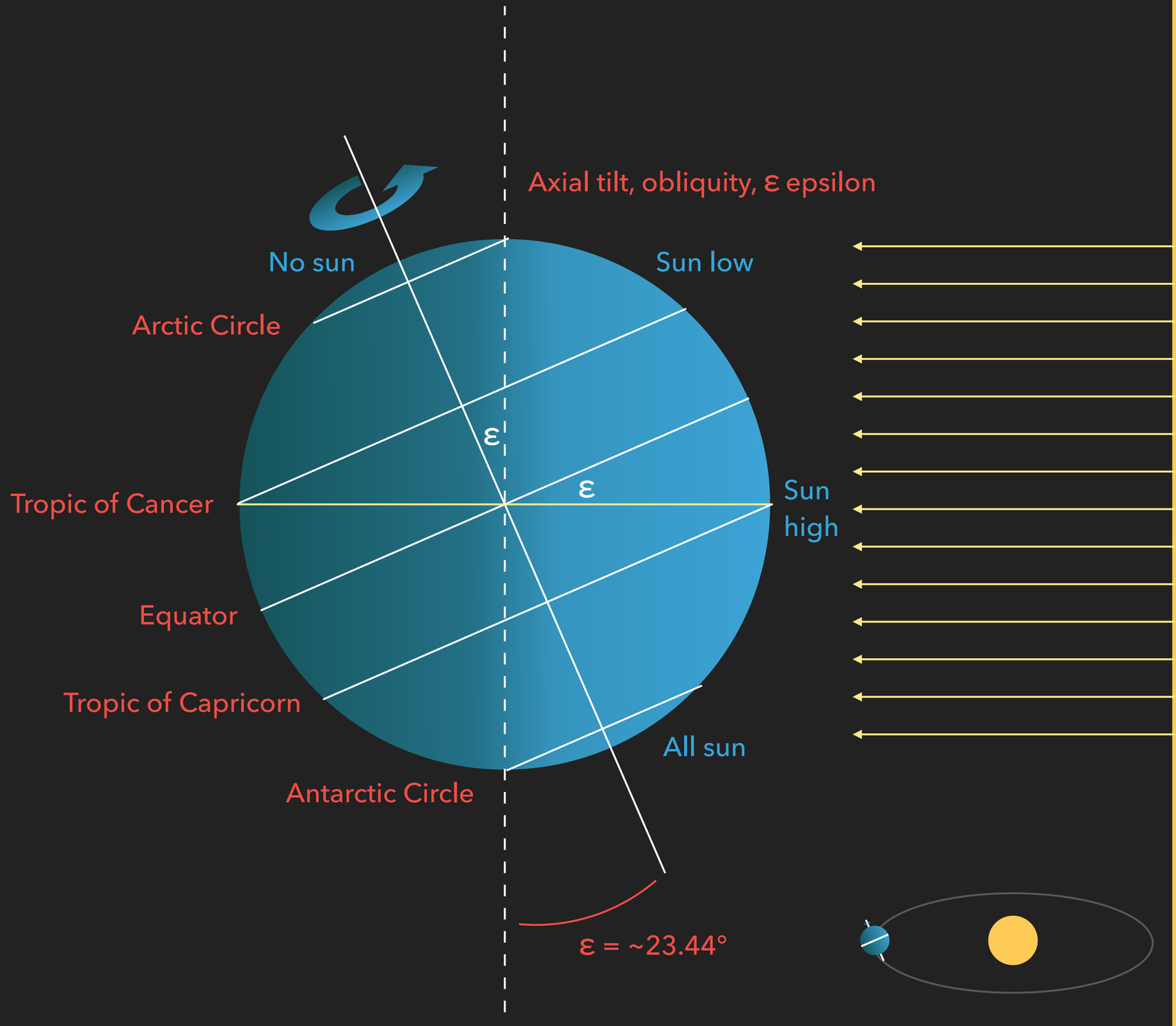


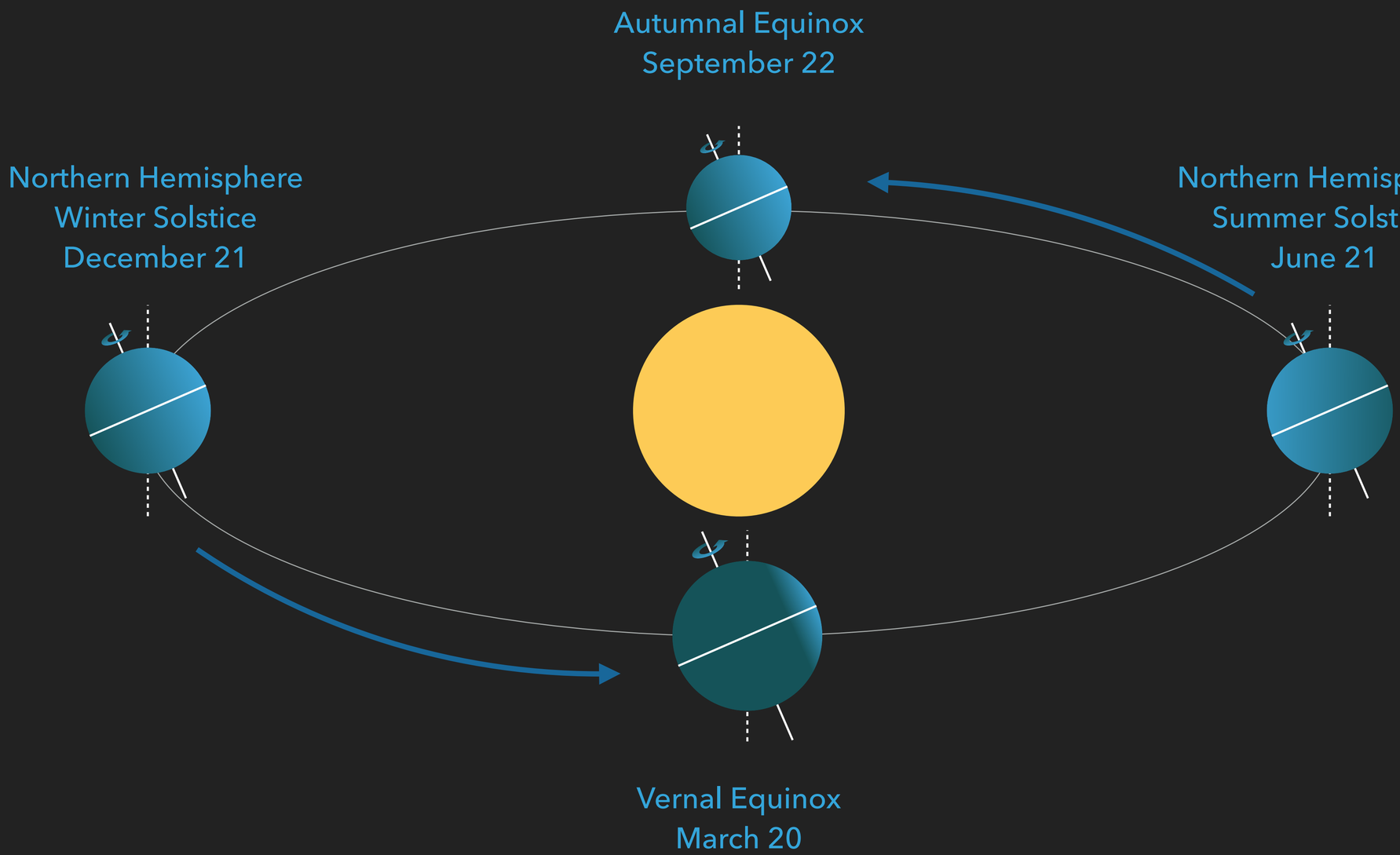

A
B



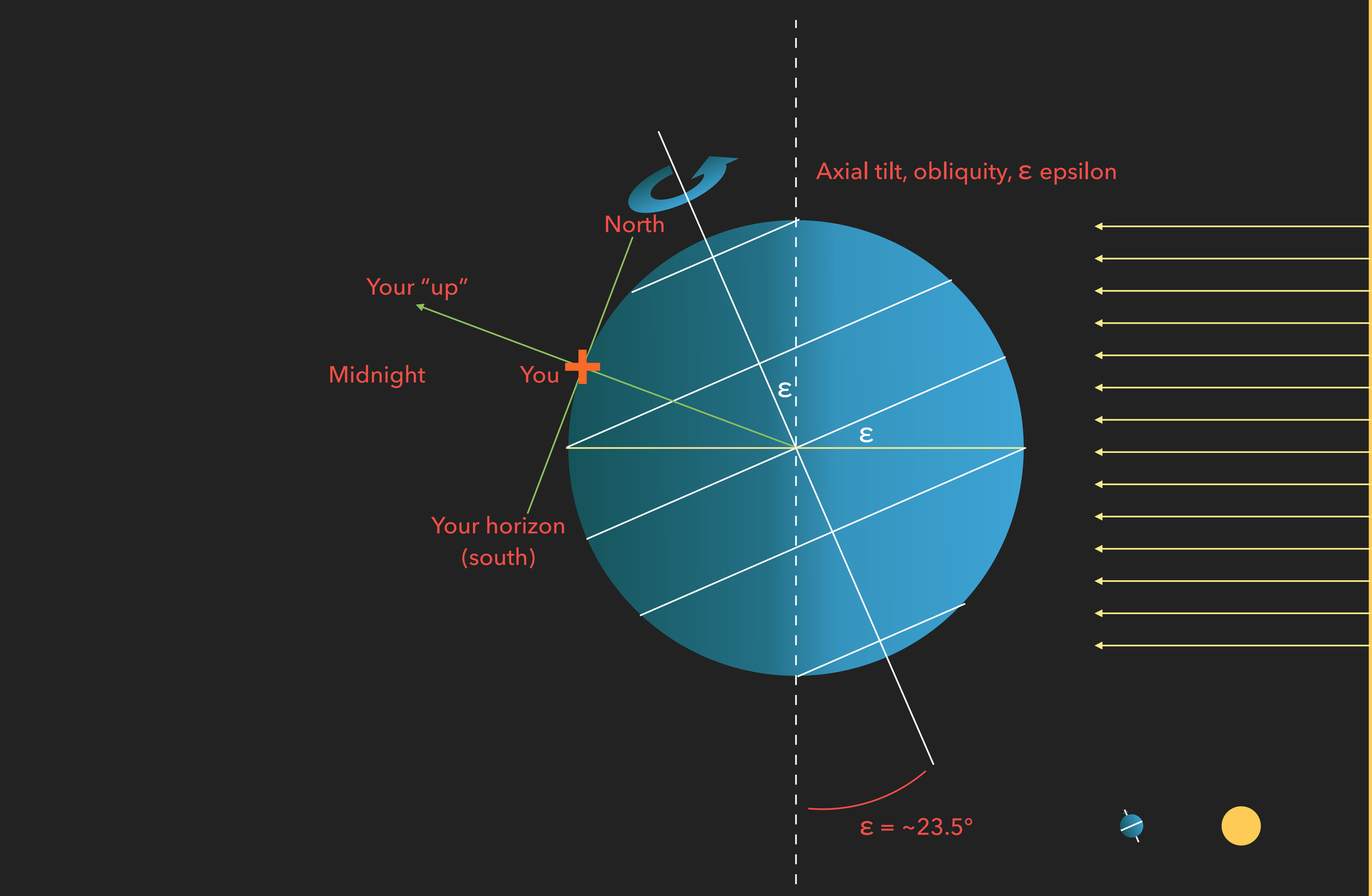



A
B
B
A

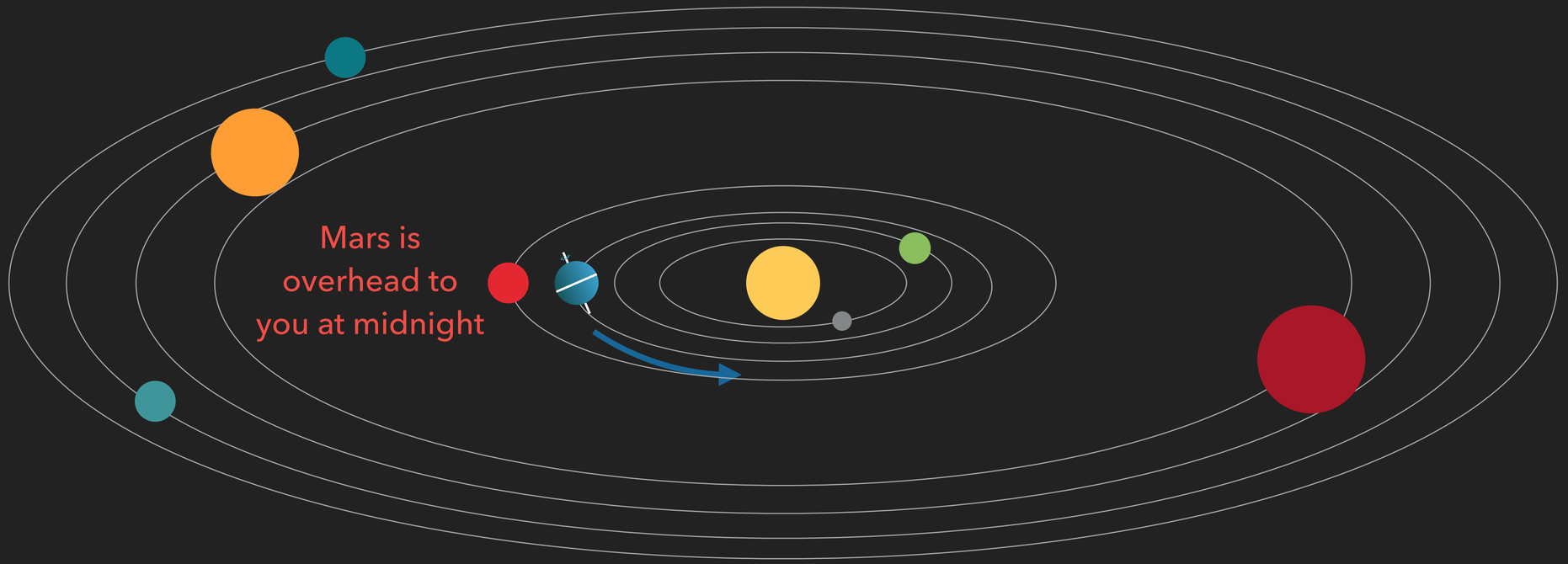

Axial tilt, obliquity, ε epsilon
No sun
Sun low
Arctic Circle
ε
ε
Tropic of Cancer
Sun
high
Equator
Tropic of Capricorn
All sun
Antarctic Circle
ε = ~23.44°

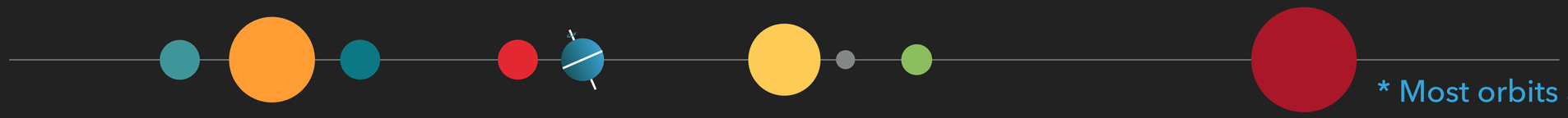

Autumnal Equinox
September 22
Northern Hemisphere
Winter Solstice
December 21
Northern Hemisphere
Summer Solstice
June 21
Vernal Equinox
March 20

(PHEW)


Axial tilt, obliquity, ε epsilon
North
Your “up”
Midnight
You
Your horizon
(south)
ε
ε
ε = ~23.5°

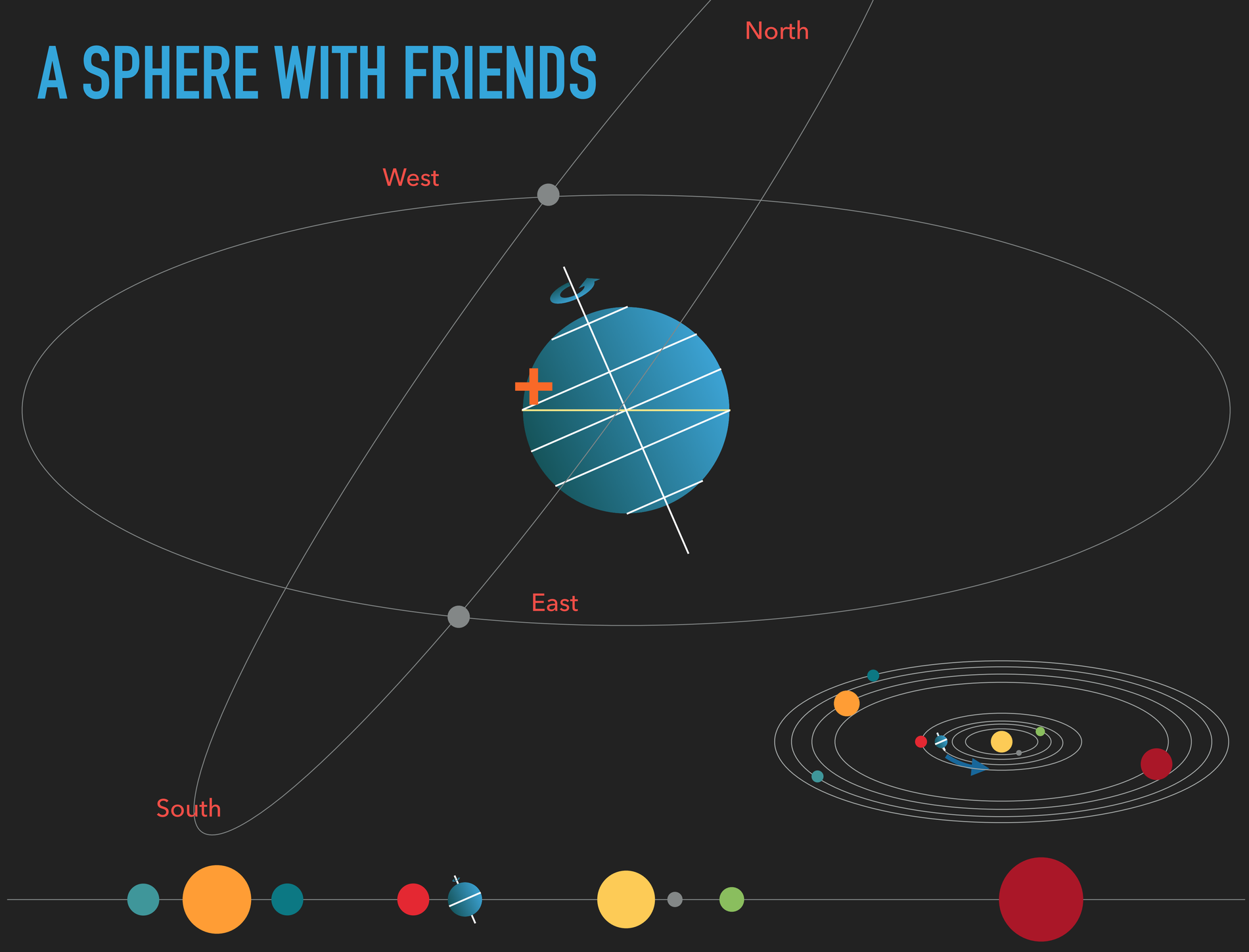
A SPHERE WITH FRIENDS

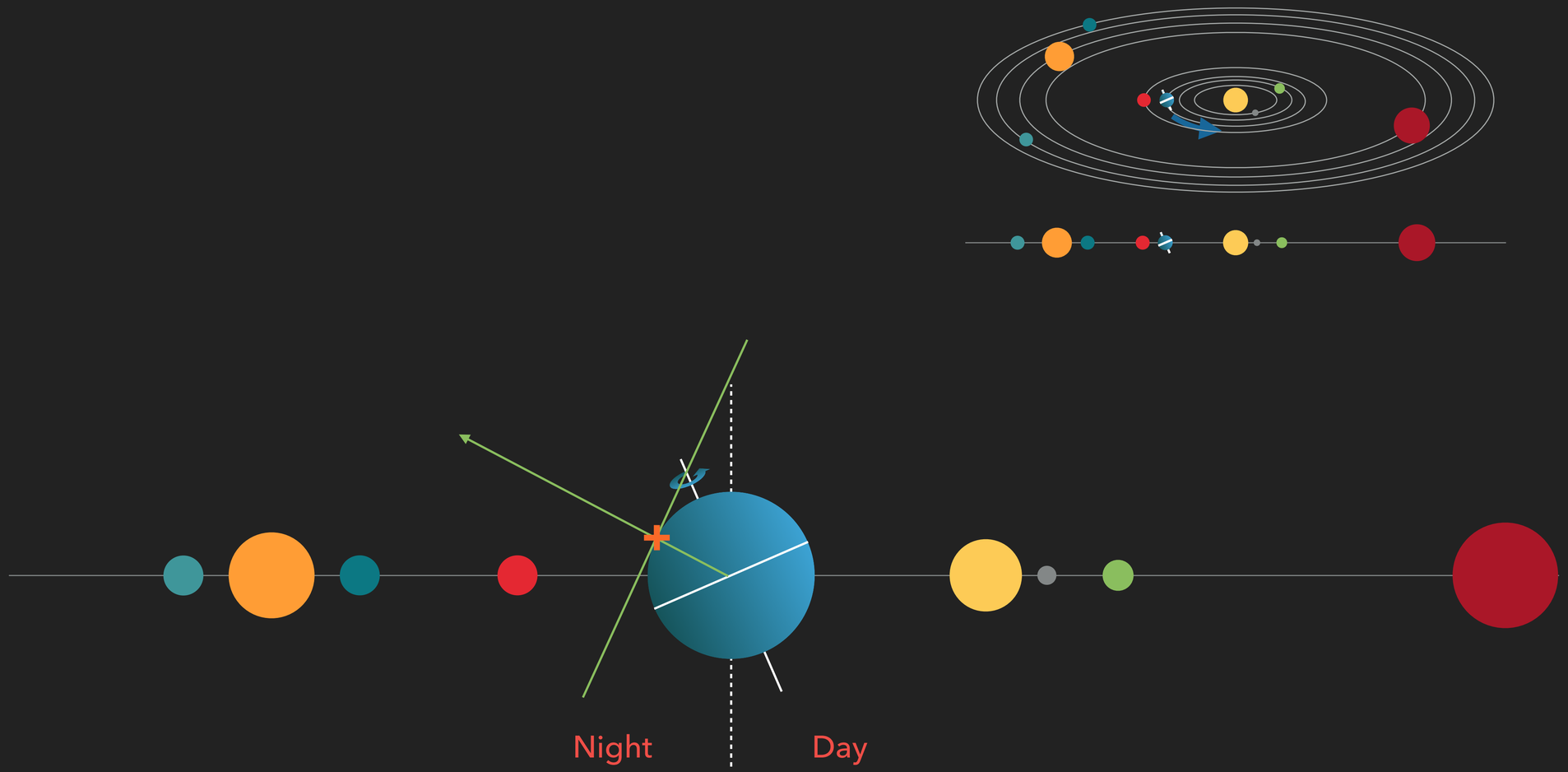




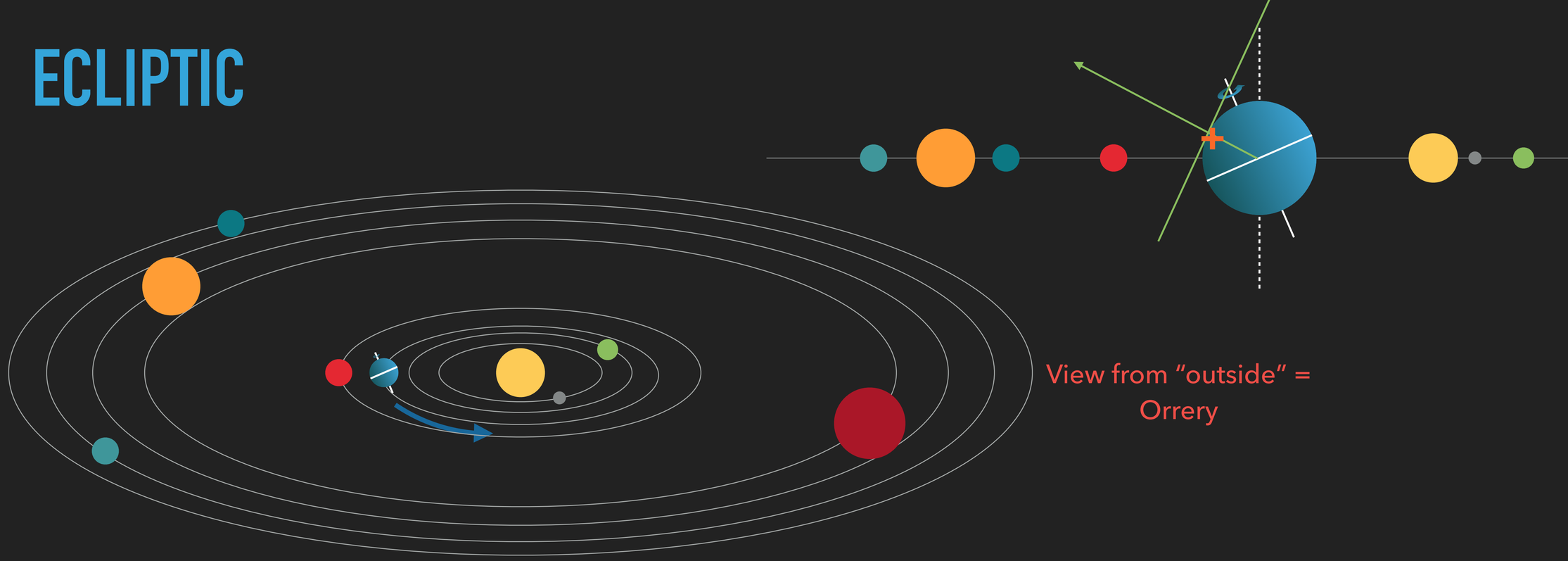
* Most orbits are close to but not strictly on the same plane

A SPHERE WITH FRIENDS




Night
Day

ECLIPTIC



View from “outside” =
Orrery

Mars is overhead

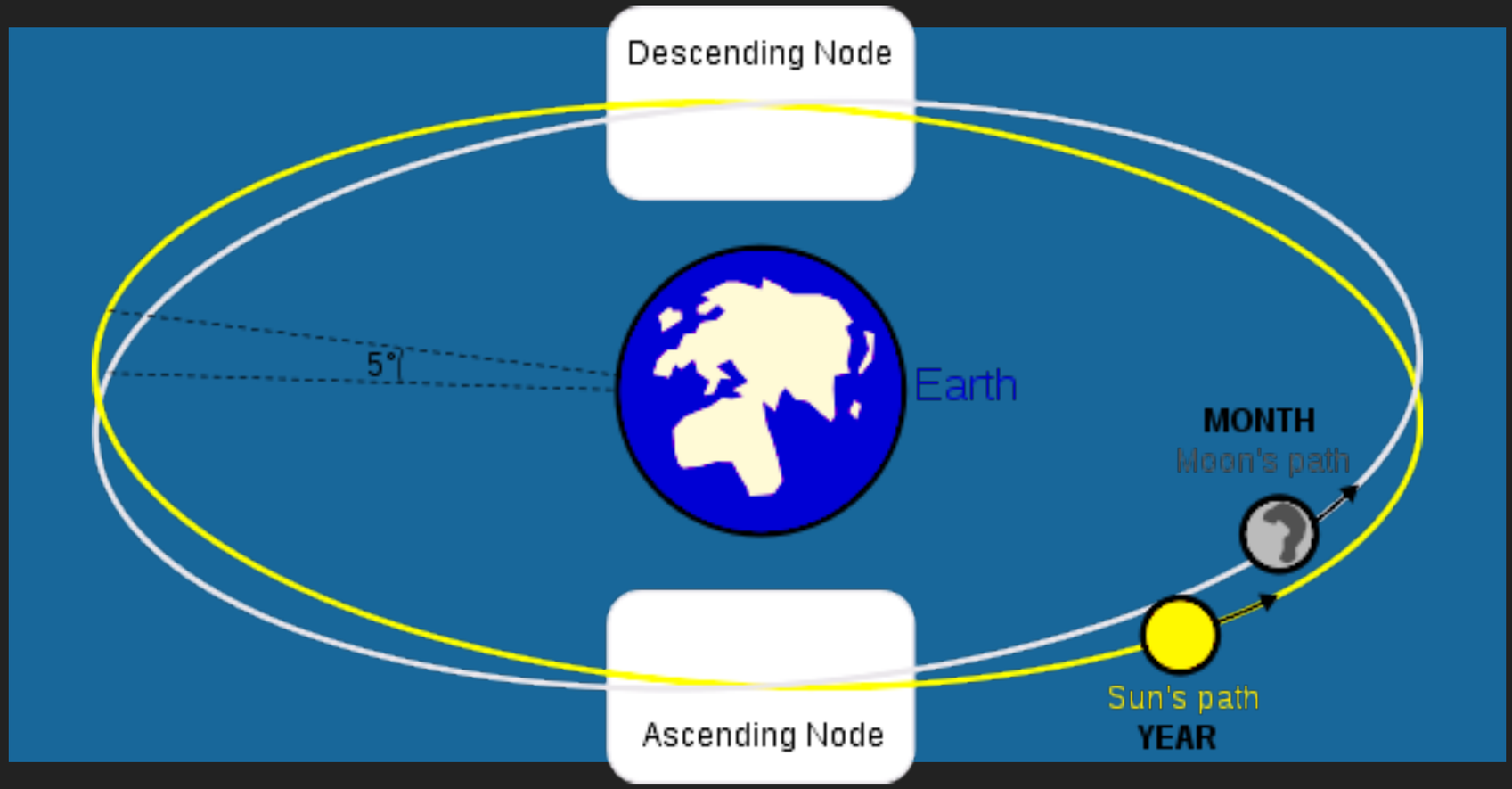
View for you =
Planetarium

South

East

West

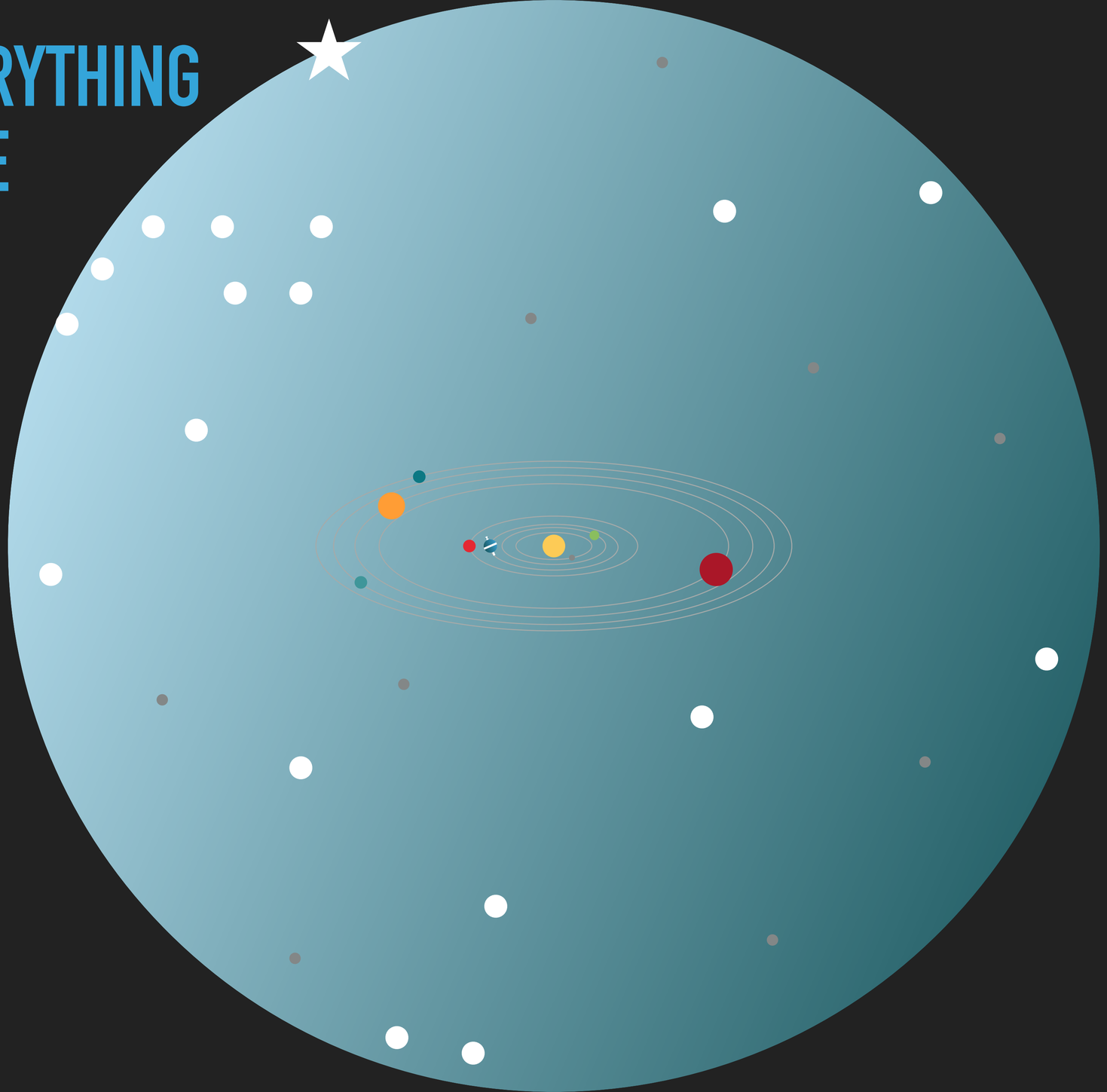
WHY “ECLIPTIC”



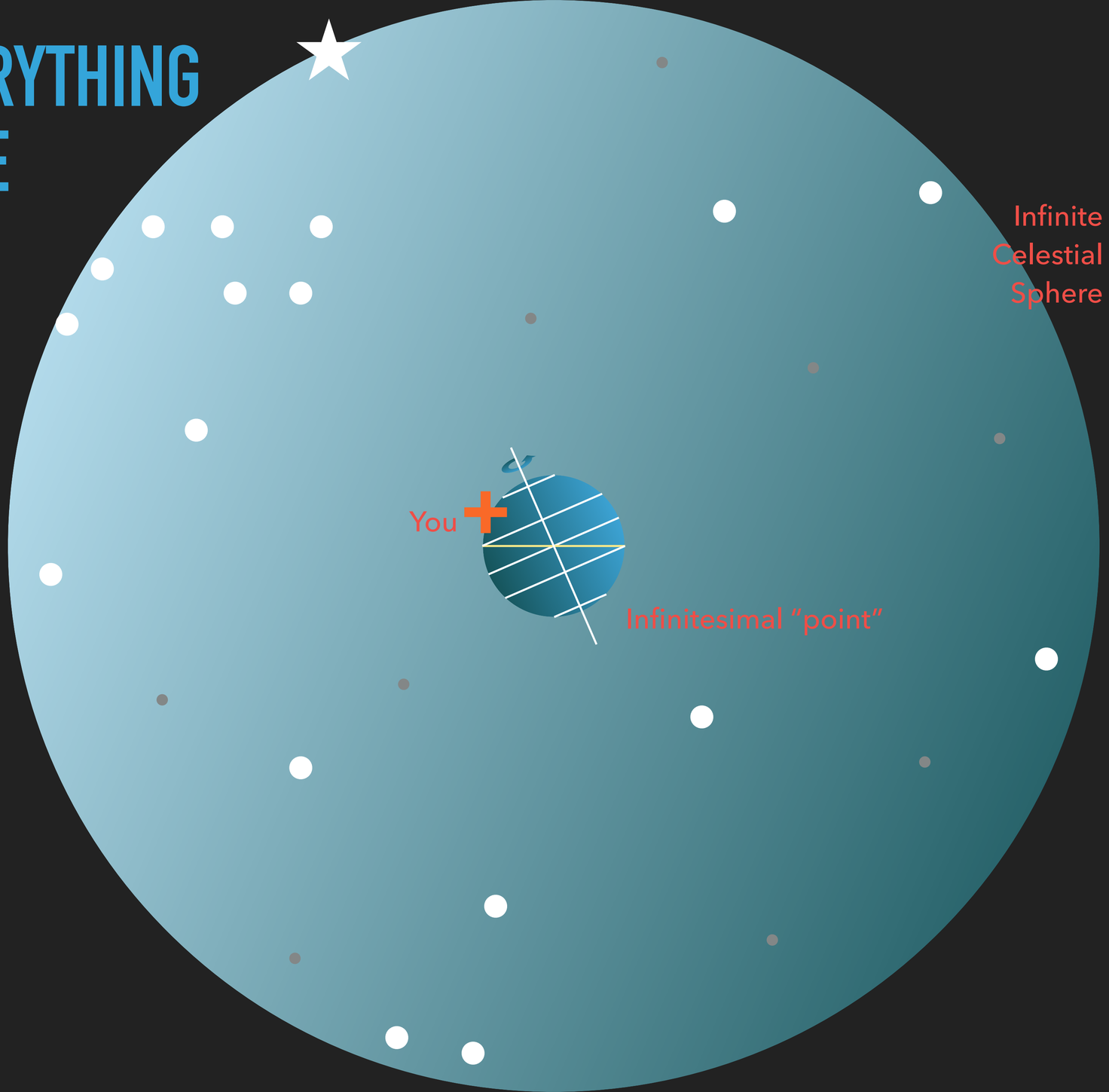
https://earthsky.org/

(PHEW X 2)

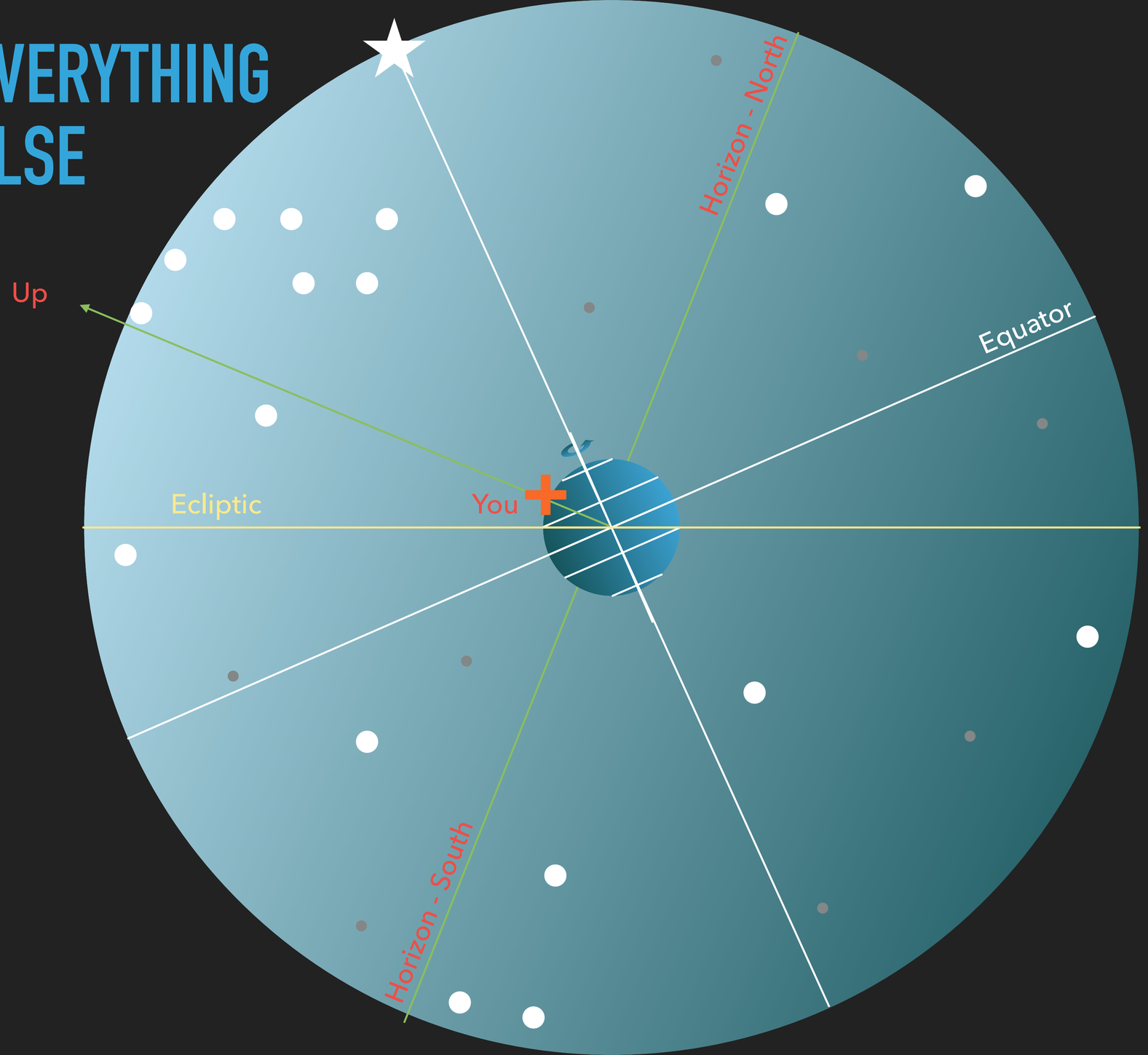
EVERYTHING ELSE

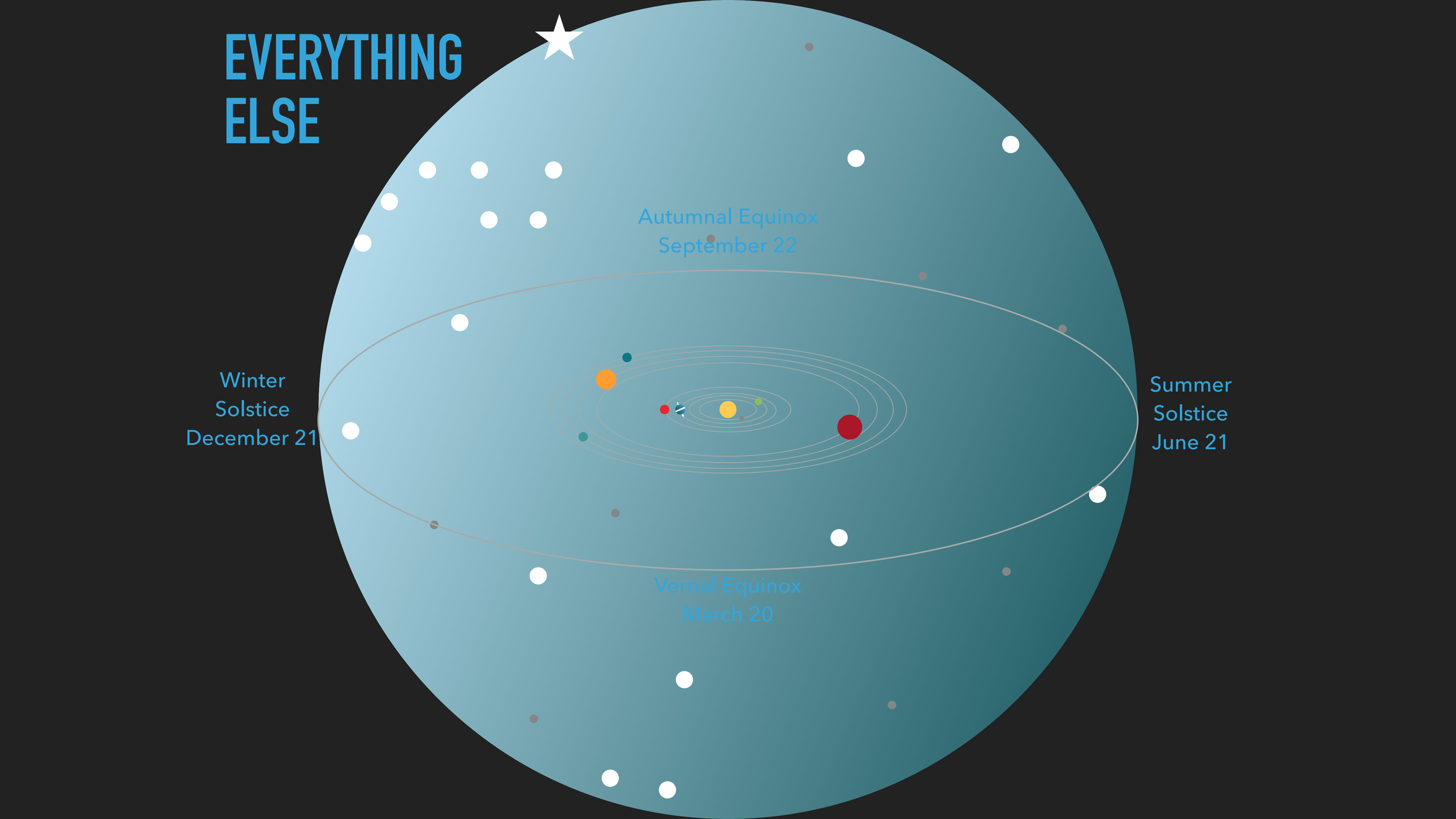


EVERYTHING ELSE

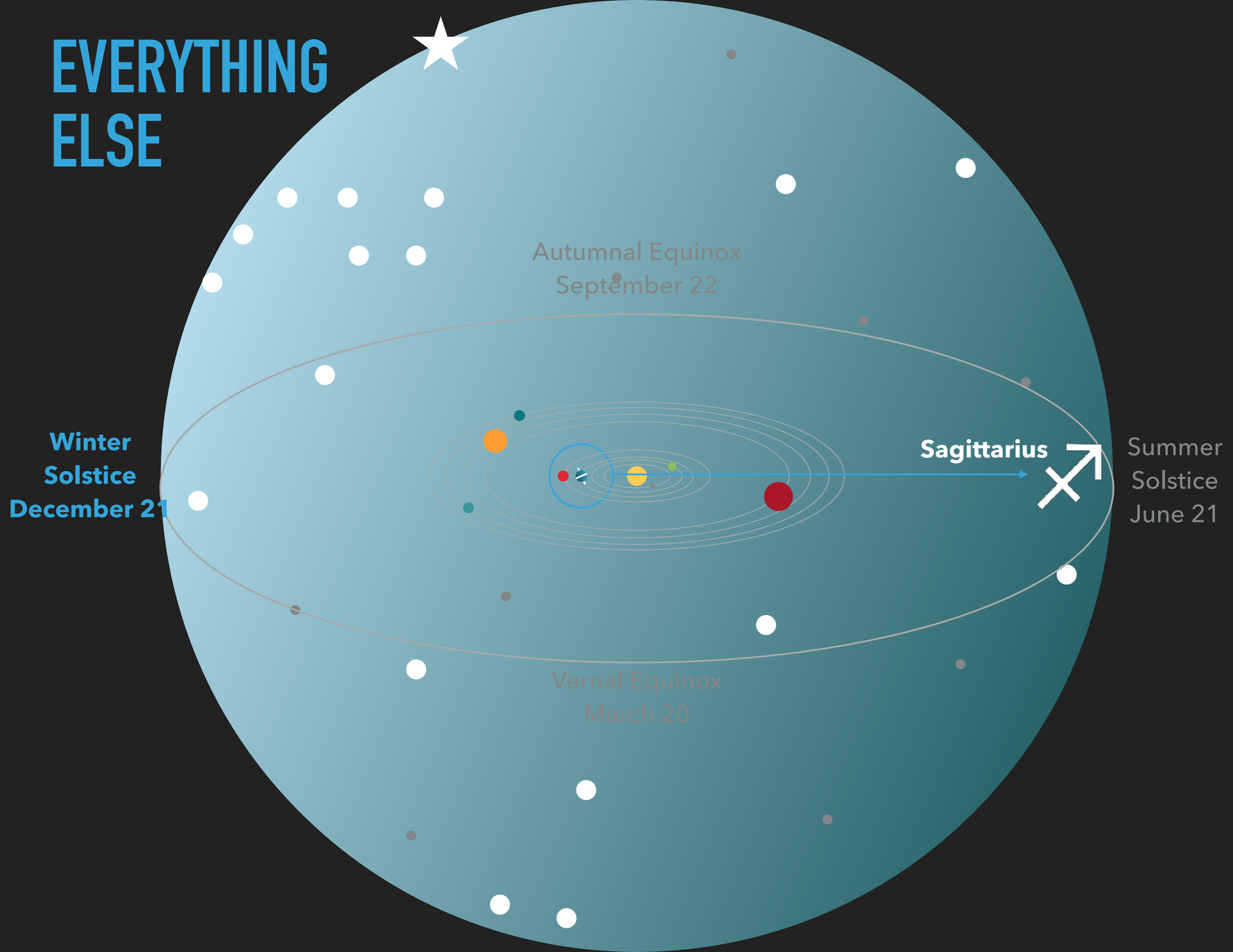


EVERYTHING ELSE

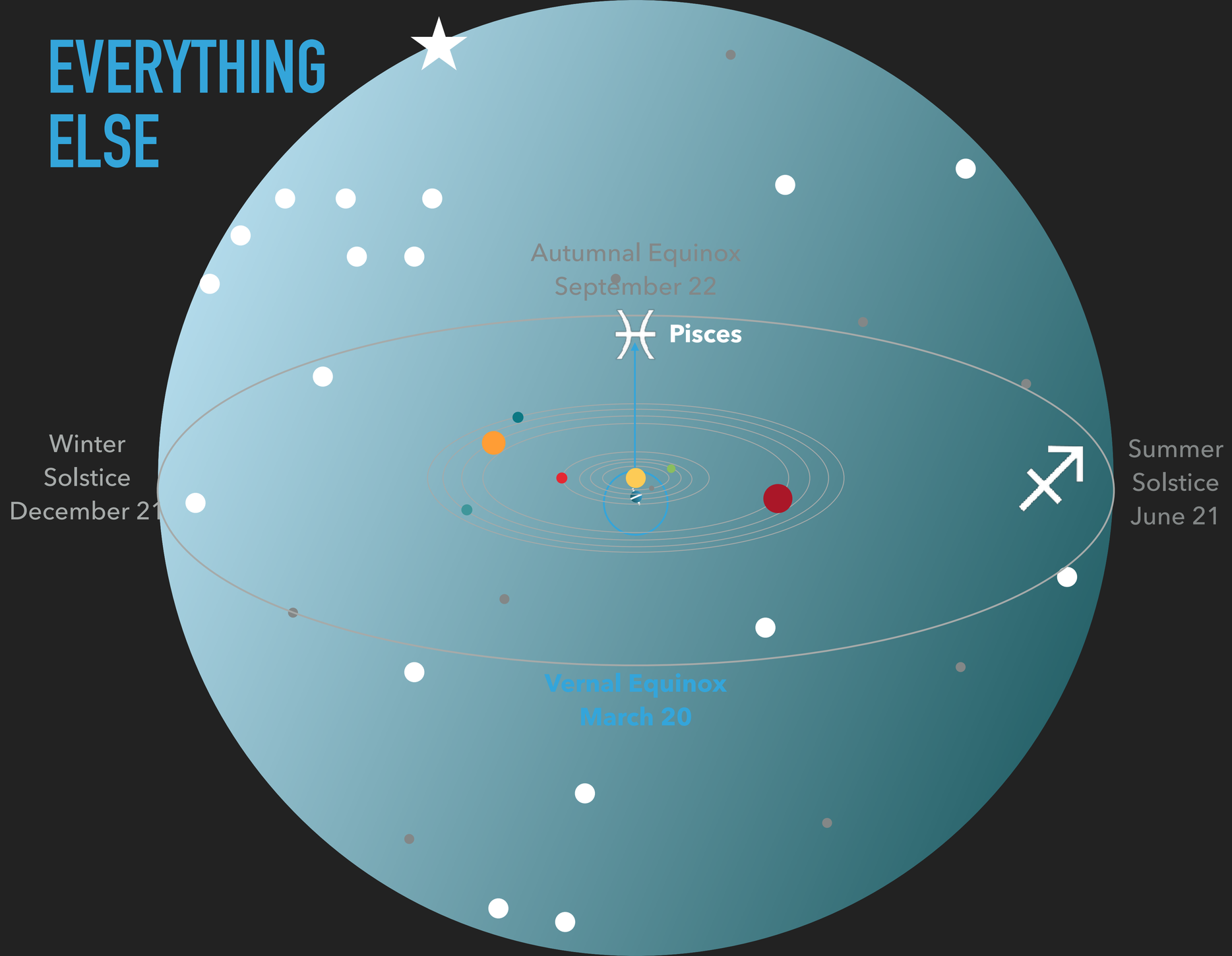



EVERYTHING
ELSE
Autumnal Equinox
September 22
Winter
Solstice
December 21
Summer
Solstice
June 21
Vernal Equinox
March 20

EVERYTHING ELSE

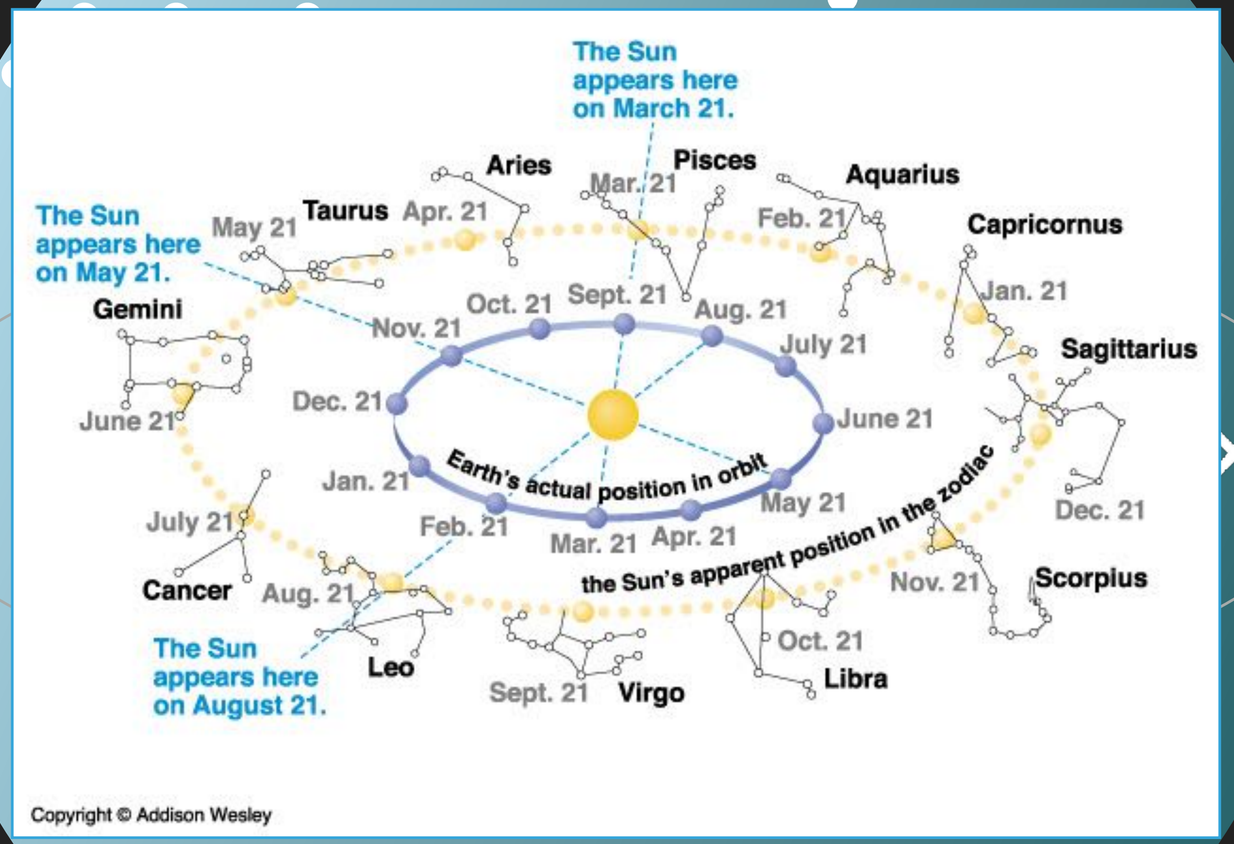


EVERYTHING ELSE



EVERYTHING ELSE

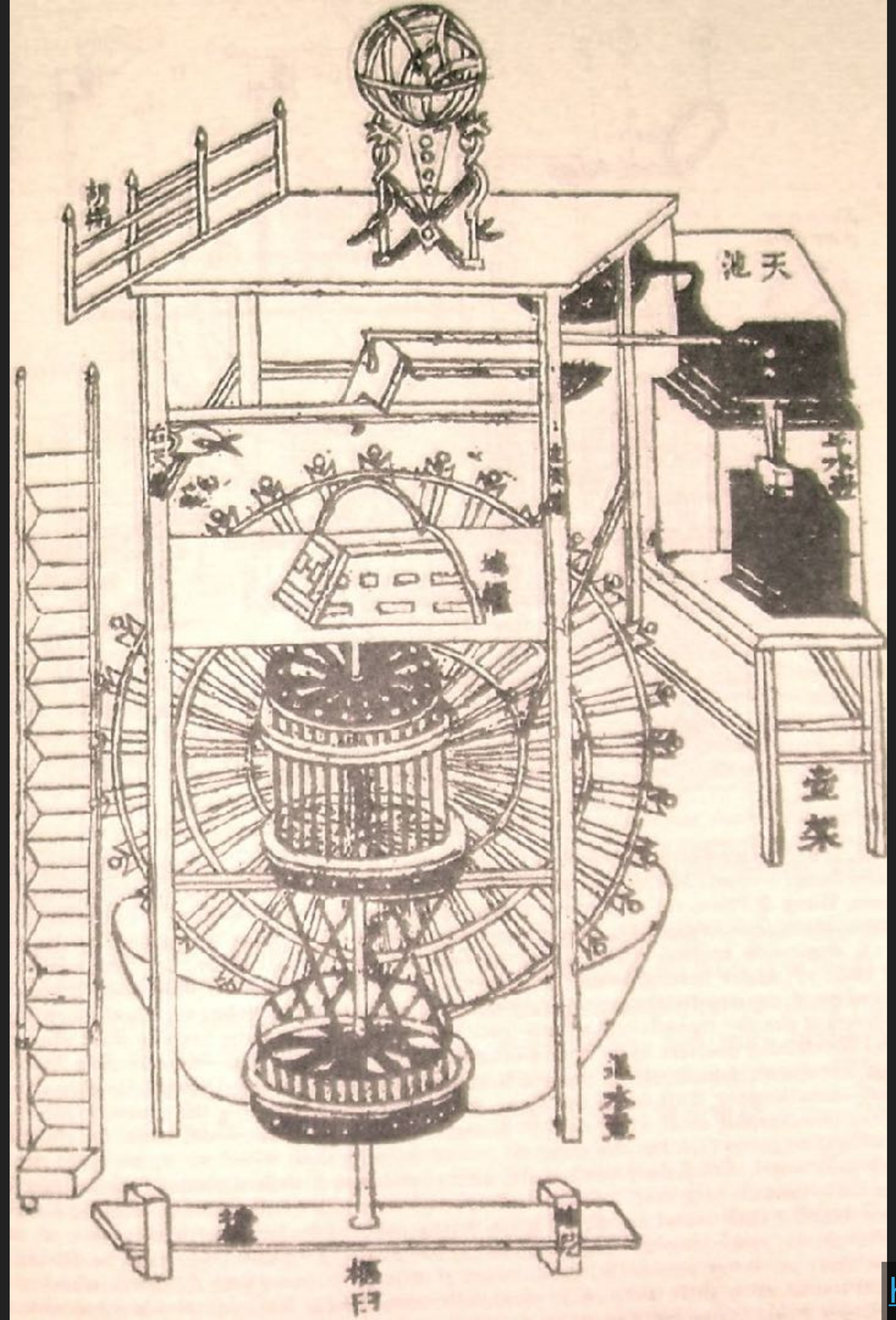
Winter Solstice December 21



Summer Solstice June 21

http://cse.ssl.berkeley.edu

(PHEW X 3)



https://www.revolution.watch/past-masters-the-astronomical-water-clock-of-su-song

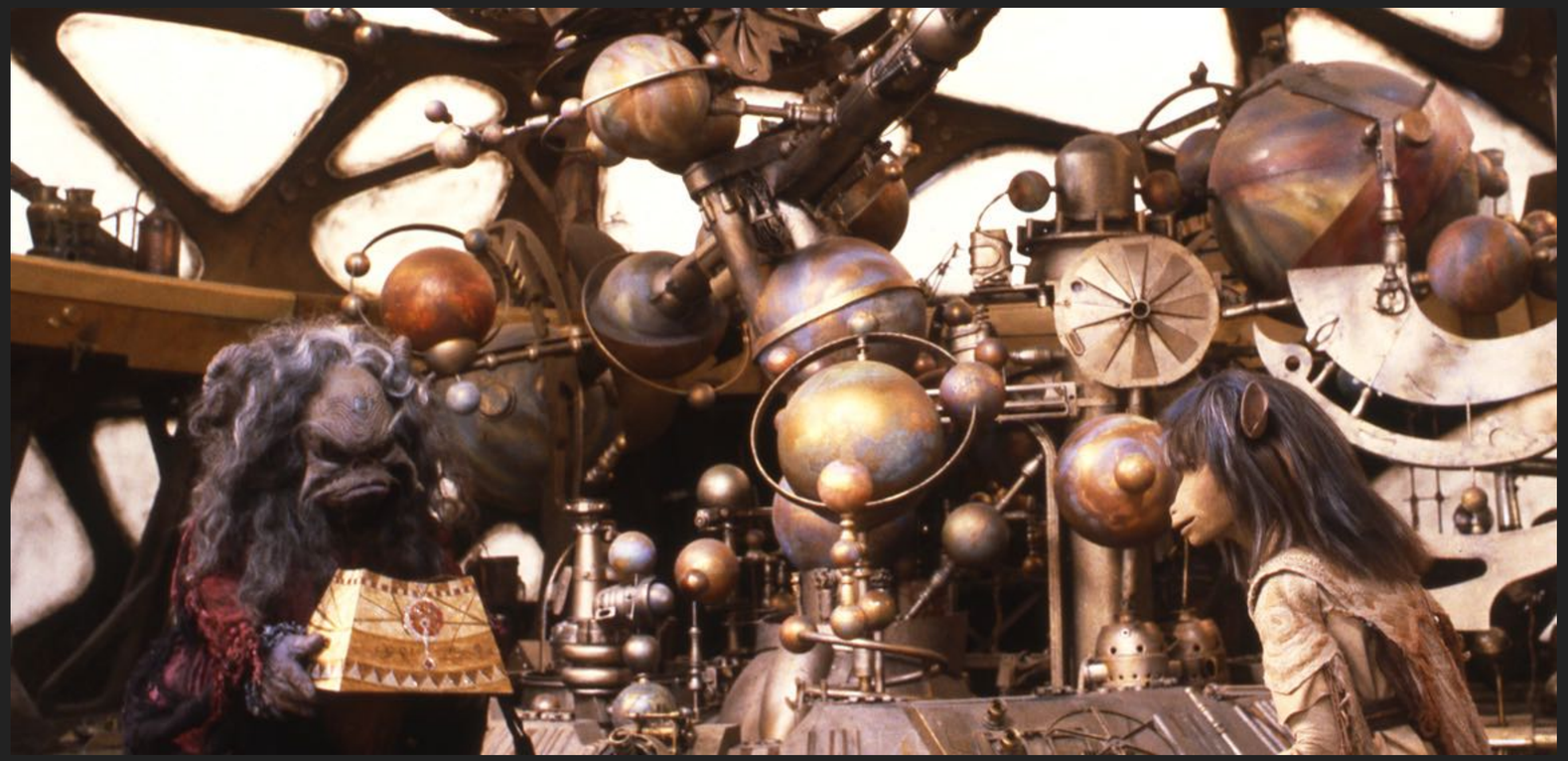
SU SONG ASTRONOMICAL WATER CLOCK

01094 CE. FIRST ESCAPEMENT

"Thus if the water is made to pour with perfect evenness, then the comparison of the rotary movements (of the heavens and the machine) will show no discrepancy or contradiction; for the unresting follows the unceasing."

ARMILLARY SPHERE MADE BY GIROLAMO DELLA VOLPAIA, FLORENCE, ITALY, 01554

London Science Museum



AUGHRA'S ORRERY

Dark Crystal

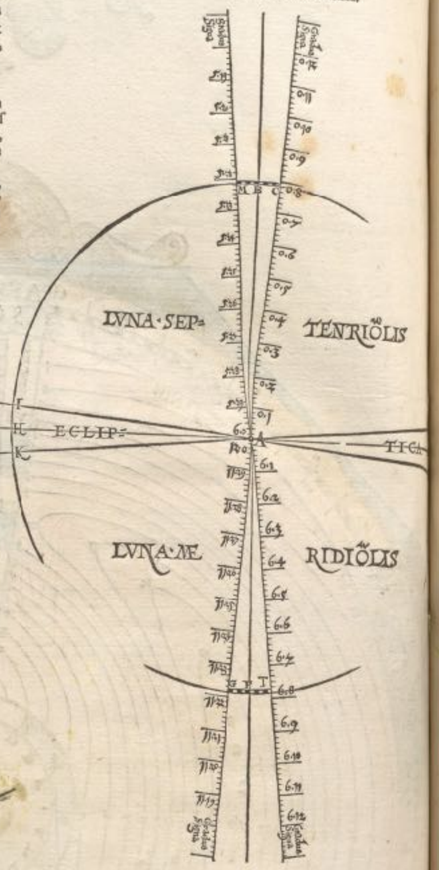
ASTRONOMICUM CAESAREUM

Petrus Apianus 1540

ENVNCIATVM VICESIMVM SEPTIM.

CAESAREVM

Hæc omnium præsens figura iterat, posterius DISPOSITORIVM dicenda.



Quomodo eclipsis Lunæ in plano sit formanda.

Ppositionem veram dici, qno futuram Lunæ obscurationem præuideras, possibilem saltem, simulatq; perspexeris, Argumenta Solis & Lunæ ad diem eundem per enunciata 12 & 25 comporta. Verum quoq; Lunæ locũ, eiusdem latitudinem, Latitudinisq; argumentum, necnon capitis draconis locum verum per enunciata 17 & 18 congere. His enim congestis, ea quæ ad eclipses attinent, cuncta conuleris. Per instrumenti ꝺ̃q; enũciũ 18 eclipsis possibilitas, tam Solis quàm Lunæ haberi potest, & melius q̃ in prio ri, hoc modo. Vbi indicem capitis draconis rite locaueris, ad tempus scz veræ oppositionis vel coniunctionis, locum quoq; Lunæ in Zodiaco contueberis, per quem filum directũ si inter d & a (Luna iuxta caput draconis morante) vel inter g & e (Luna caude draconis vicina) cecideriẽ, fateri aude Lunam in illa oppositione defecturam. Vicissim Solis defectum conspicaberis in ꝺ̃ne quadã hac lege. Tempora ꝺ̃nis veræ cum filo signa, quod si inter b & c iuxta caput draconis, vel inter f & g iuxta caudam draconis feratur, contingens est Solis deliquium in hac coniunctione. Vertũ Solis obscurationes propter aspectuum diuersitates non ita ad vnguem, sine calculandi opera, sicut Lunæ haberi nobis potuerunt, eas tamen, deo volente, in posterum quoq; in instrumenti formam redacturos nos, quo ad licebit, nõ diffidimus. Possibilitate eclipsis Lunaris agnita, lineam in plano aliquo præscribe, quam H D nomina, cuius medium A sit. Huic alia perpendicularis inducta B F dicatur. Pedem nunc circini alterum in A litera fige, extensus alter circulum occultum pro Arbitrio scribat, qui idem in linea B F & punctis B F fecetur. Eo facto Lunæ latitudinem considera, quæ si Septentrionalis fuerit, tum oportebit Argumentum eius verum esse 5 Signorum & 18 graduum ad minus, vsq; in 6 Signa etiam, vel Signi nullius, graduumq; 12. Iam si Argumentum sit Signi nullius, diuidatur quarta B D in 18 partes lic. primo in tres, deinde singulas in alias tres, postea quamlibet in duas, & habebis 18 portiones, quarum siugulæ 5 gradus continent. Proximo B literæ puncto C ascribe, rectamq; lineam à centro A per C educito. Si vero Argumentum latitudinis Signorum sit 5, tum B H quartam dispesce, primæ autem post B literam sectioni, M literam appone, perq; M & A centrum lineam, vt antea, diduc. Quod si meridionalem Lunam conspexeris, Argumentum habens 6 Signorum, & insuper aliquot graduum, tum ab F litera D versus proximum punctum elige, eundem cum T litera signans. Argumento 11 Signorum existente, ab F versus H cum puncto huiusmodi digredere, cui ascribe G. Hac in parte nõ mouearis quicquam, si gradus aliquando Signis non adiunctos videas, obseruatis diligenter Signis tantummodo.

Hæc omniũ &c.

Deinde in limbo exteriori sequentis figuræ, quæ post hac, instrumentum Semidiametrale vocabitur, Solis Argumentum vestiga, cui filum vbi superposueris, nota eiusdem, & limbi interioris (quæ vmbrarum varietates per secunda metitur) contactum, secunda vero illa à filo abscissa, seorsum excipe. Argumentum deinde Lunæ perquirens, cum filo pariter transmisso signa, quod filum binas tibi corporis vicz Lunaris & vmbræ terræ, semidiametros aperit. Filo sic durante, circinum in centro fige, pede altero in punctũ vsq;, in quo nigrior area à filo tangitur, extenso, illa enim extensio semidiameter corporis Lunæ est, quam ita inuariatam reserua. Alium post hac circinum fini prioris diametri iam habiti infige, Pedem alterum eiusdem circini vsq; ad areæ fuscæ terminum protendens, semidiametrum quoq; vmbræ terrenæ habebis. Aream hanc circunferentia quadam candenti circuncirca includi vides, vltra quã aliam, caiami latitudine, superficiem cernis, quæ in 60 secunda distributa est. Sed cum iam antea secunda varietatæ vmbræ didiceris, pedes circini pro tot secundorum distantia contrahi debent, & vera vmbræ semidiameter habebitur. Talem postea circinum in A plani prius ad hoc præparati, vbi firmaueris, circulumq; descripseris, veram vmbræ quantitatem cernis, vmbræ inquam terræ, quæ in Lunæ transitu, oppositionis illius tempore fit. Mox in instrumento cui nomen dispositorio, Lunæ Argumentum in lineis, siue A C siue A M, siue A G, siue A T sit, contemplator. Loco oblato pedem circini infere, extendaſq; alterum in argumenti punctum. Eandem postea circini extensionem parato plano infer, pedeq; altero in A fixo, cum altero punctum in linea paulo antea, huic rei deputata, exprime, literaq; M signa. Iam circinum require, extensum, iuxta corporis Lunaris semidiametrum, quem vbi fixeris in M, cumq; eodem circulum describeris, corpus Lunæ te habere pura. Ex illis nunc demum certus esse potes, de contingenti huius oppositionis eclipsi, deq; quantitate eiusdem. Si enim corpus Lunæ totum sub vmbram concesserit, vniuersalis, si partim, particularis, sin omnino non, nulla eclipsis euenit.

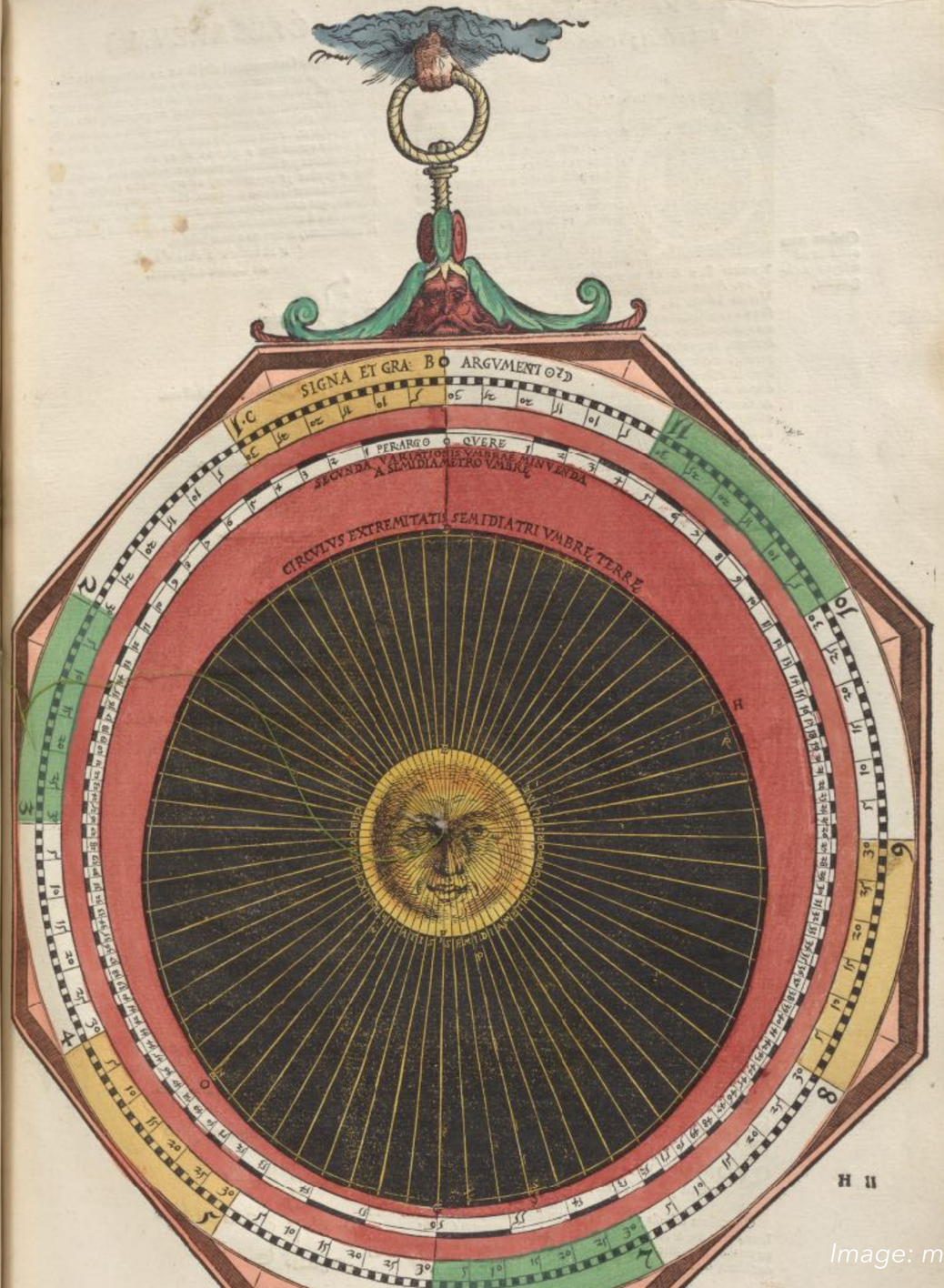


Image: metmuseum.org

ASTRONOMICUM CAESAREUM

Petrus Apianus 1540

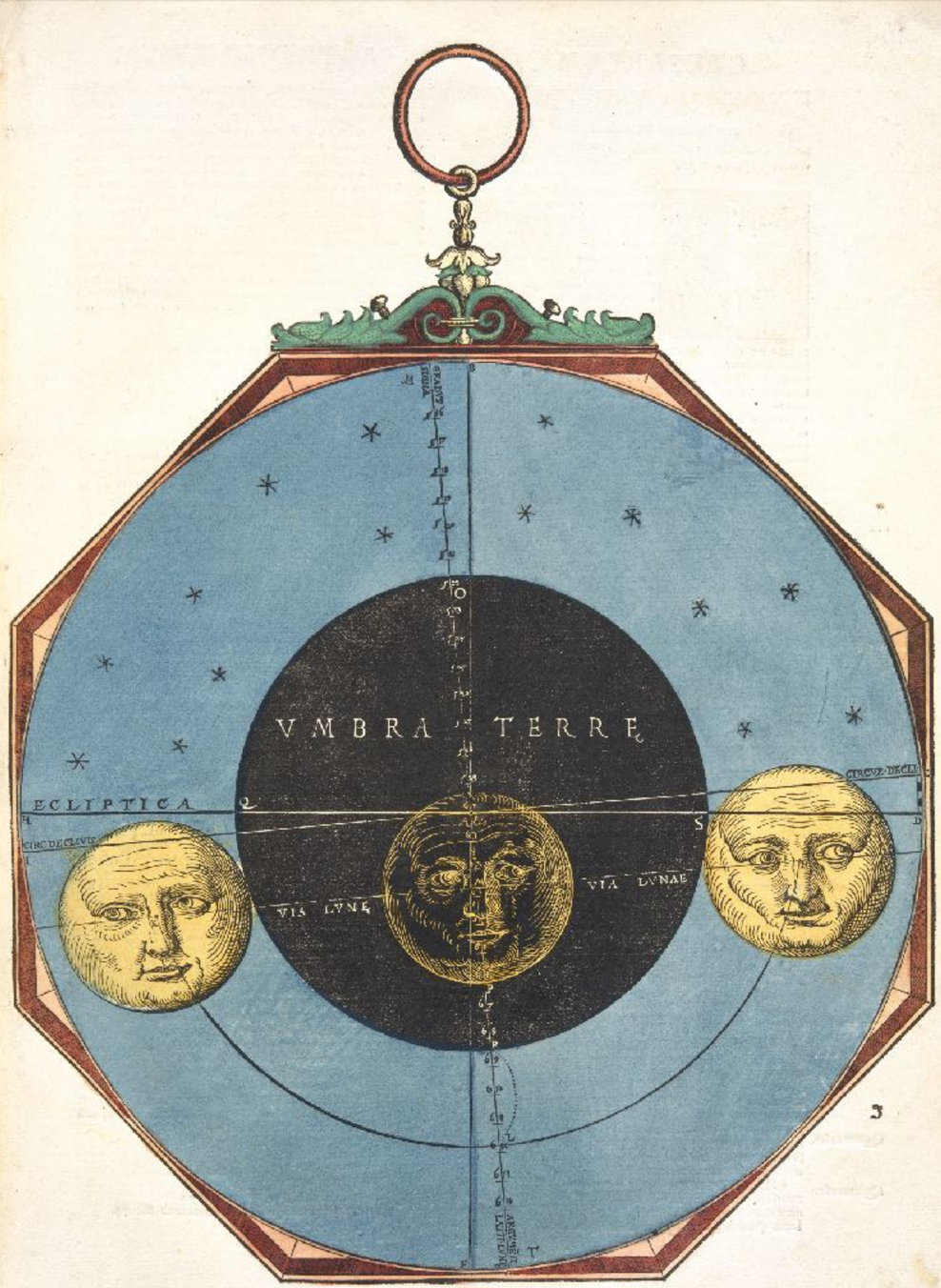


Image: metmuseum.org

PLANISPHERIC ASTROLABE

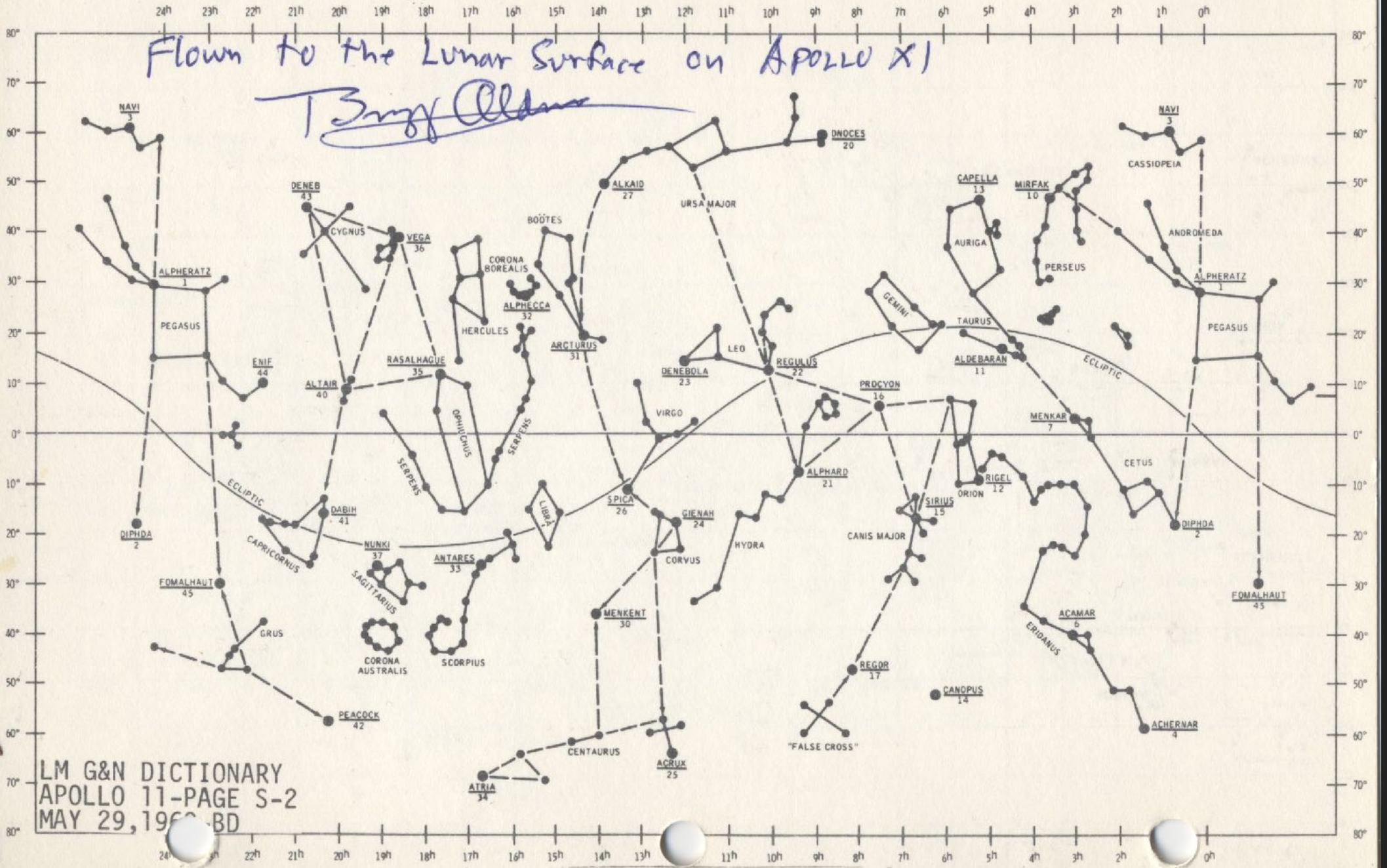
Maker: Muhammad Zaman al-Munajjim al-Asturlabi (active 1643–89)

Image: metmuseum.org

STAR CHARTS

Flown to the Lunar Surface on APOLLO XI

T Buzz Aldrin

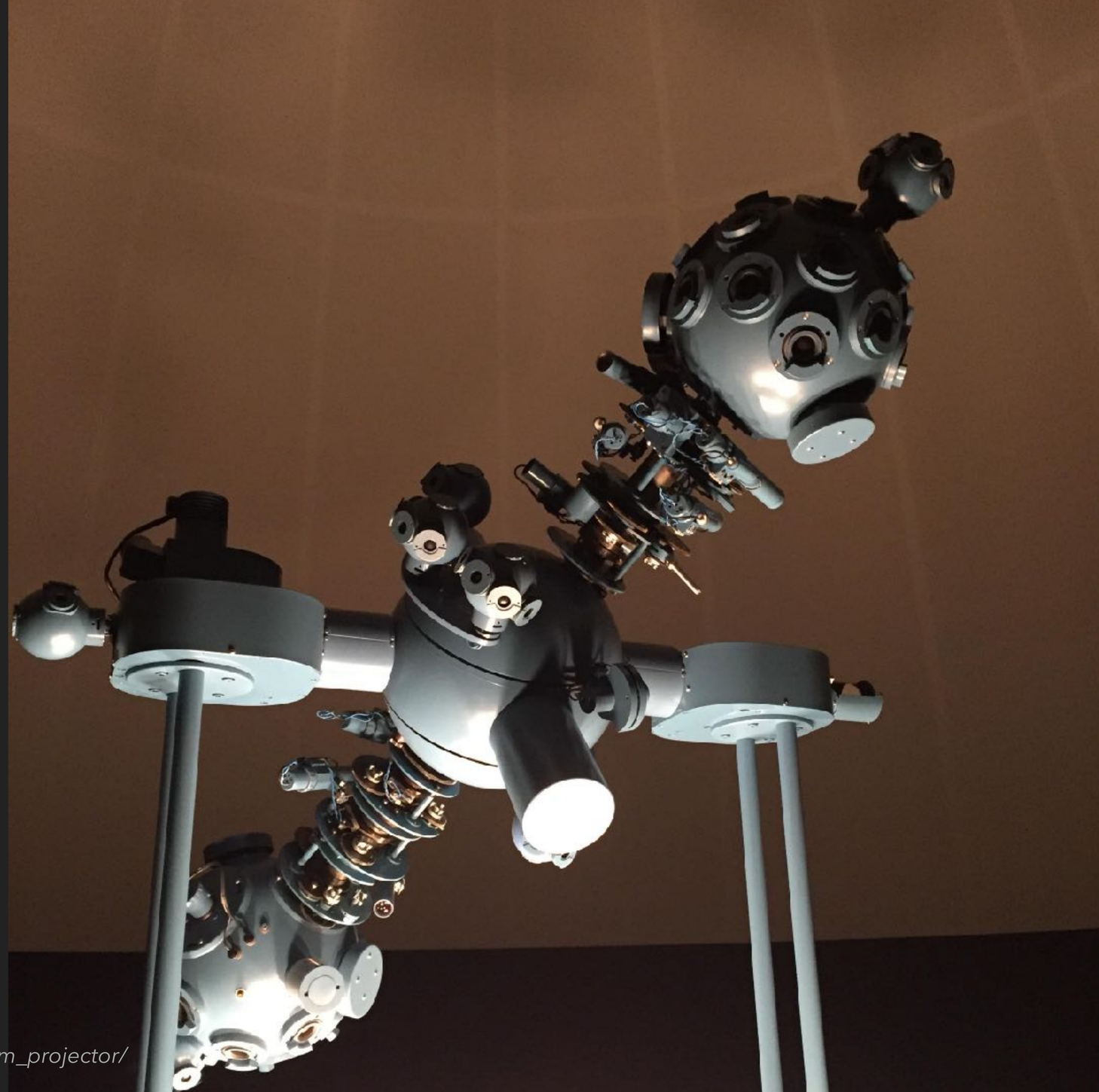


LM G&N DICTIONARY
APOLLO 11-PAGE S-2
MAY 29,196[illegible]-BD

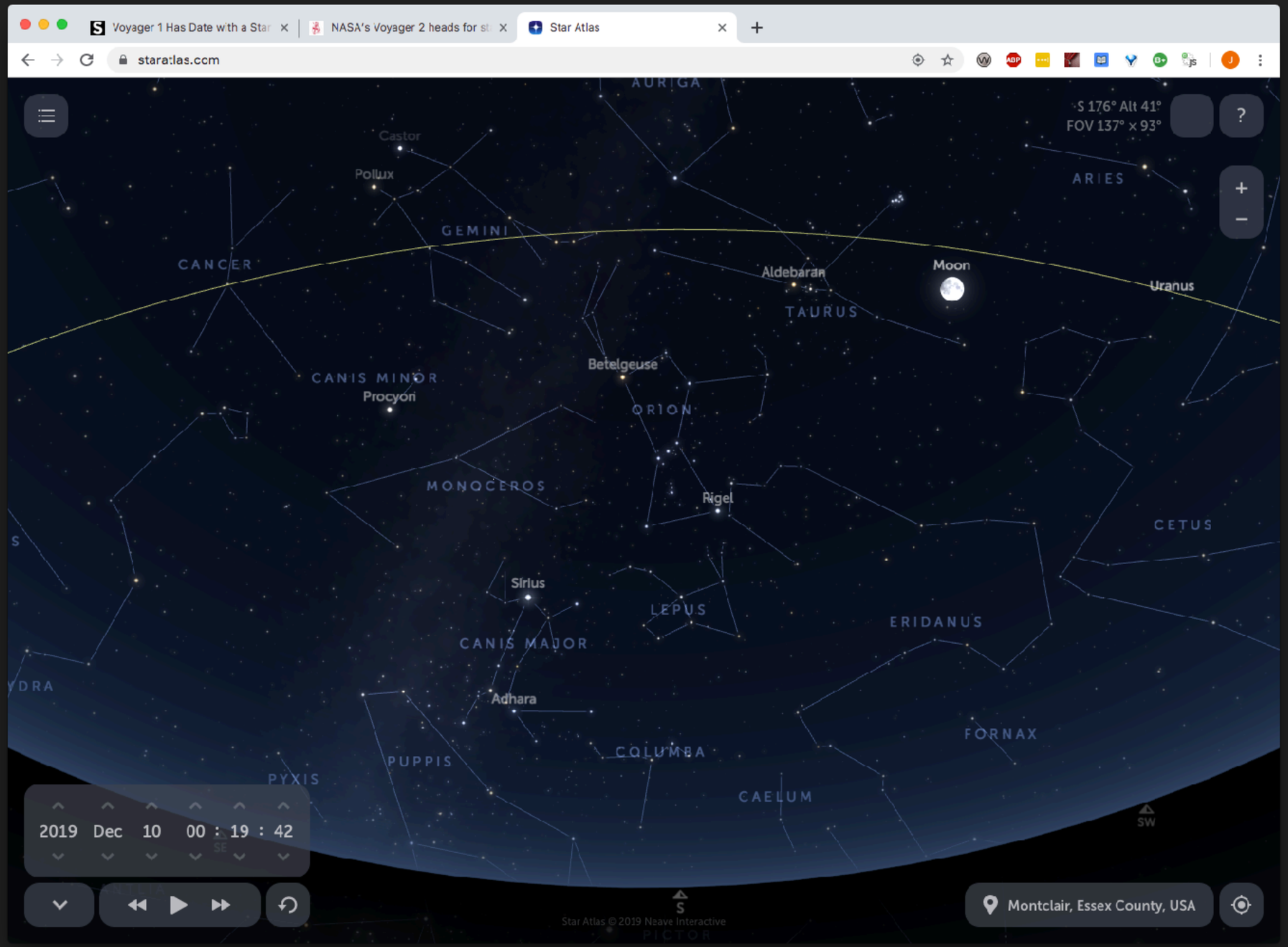
SOYUZ CELESTIAL NAVIGATION GLOBE

http://www.collectspace.com/ubb/Forum14/HTML/001394.html

ZEISS STAR PROJECTOR



https://www.reddit.com/r/specializedtools/comments/8b3aq3/old_zeiss_planetarium_projector/


Voyager 1 Has Date with a Star
NASA's Voyager 2 heads for st
Star Atlas
staratlas.com
S 176° Alt 41°
FOV 137° × 93°
AURIGA
Castor
Pollux
GEMINI
CANCER
ARIES
Aldebaran
Moon
Uranus
TAURUS
Betelgeuse
CANIS MINOR
Procyon
ORION
MONOCEROS
Rigel
CETUS
Sirius
LEPUS
ERIDANUS
CANIS MAJOR
Adhara
FORNAX
COLUMBA
PUPPIS
PYXIS
CAELUM
2019 Dec 10 00 : 19 : 42
SW
S
Montclair, Essex County, USA
Star Atlas © 2019 Neave Interactive

HOW BIG IS THE UNIVERSE?

Why do we care? Because time and space are related. Age and size of the universe are related. Reasoning about **where we are** in the universe is related to reasoning about **when we are**.

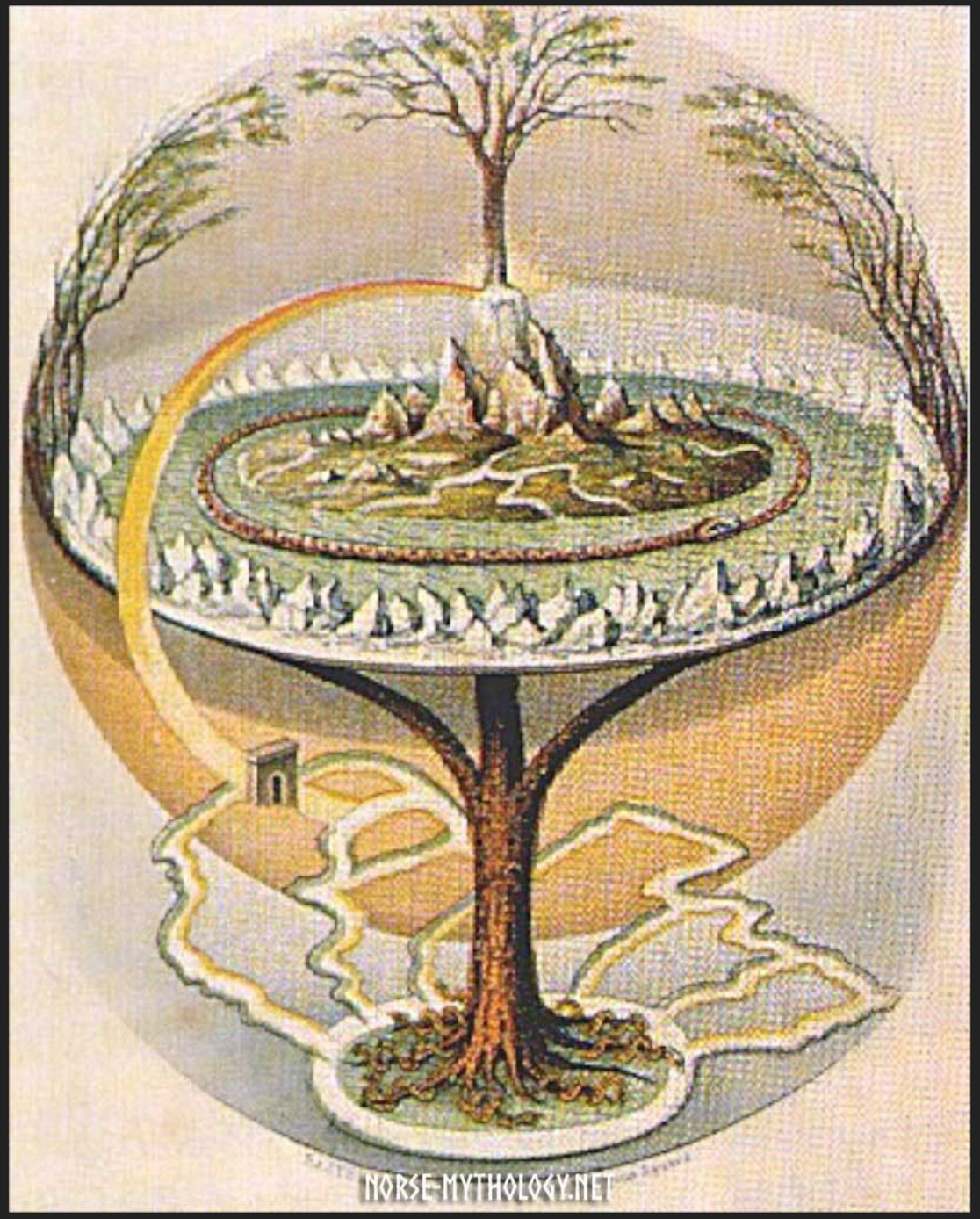
Also - there's a very cool story about the discovery of a **stellar clock** that unlocked our understanding of the size and age of the universe. Stick around till the end!!

COMIC DISTANCE LADDER

See: Mentalfloss, The Expanding Universe: How the Universe Got Bigger As We Measured It and Terrance Tao (UCLA), Cosmic Distance Ladder

GEO METRY

EARTH MEASURE



YGGDRASIL THE WORLD TREE NORSE

https://norse-mythology.net/yggdrasil-in-norse-mythology/

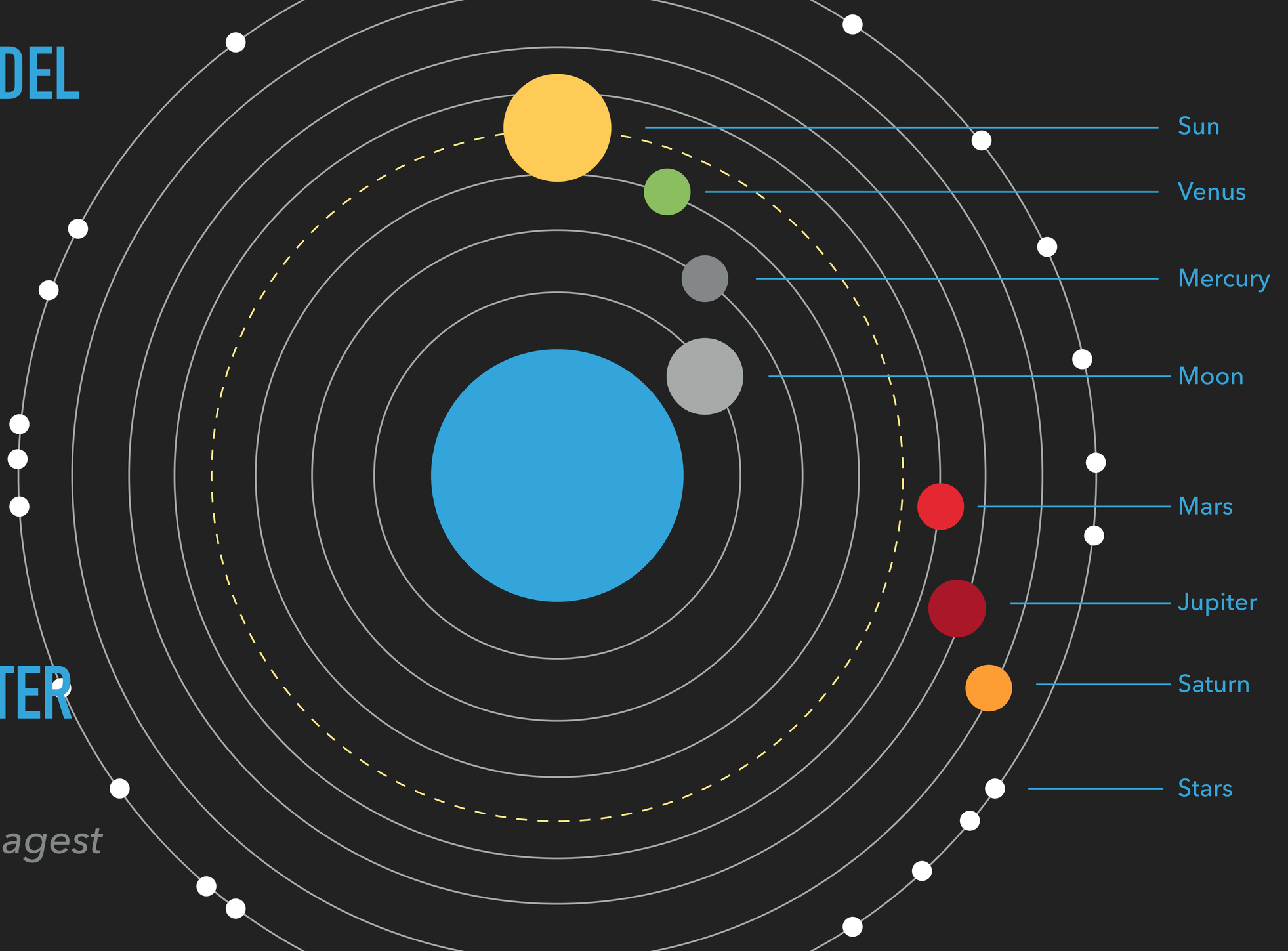
PTOLEMAIC MODEL
GEOCENTRIC

WE'RE THE CENTER OF EVERYTHING

Detailed in the Almagest

~150BC

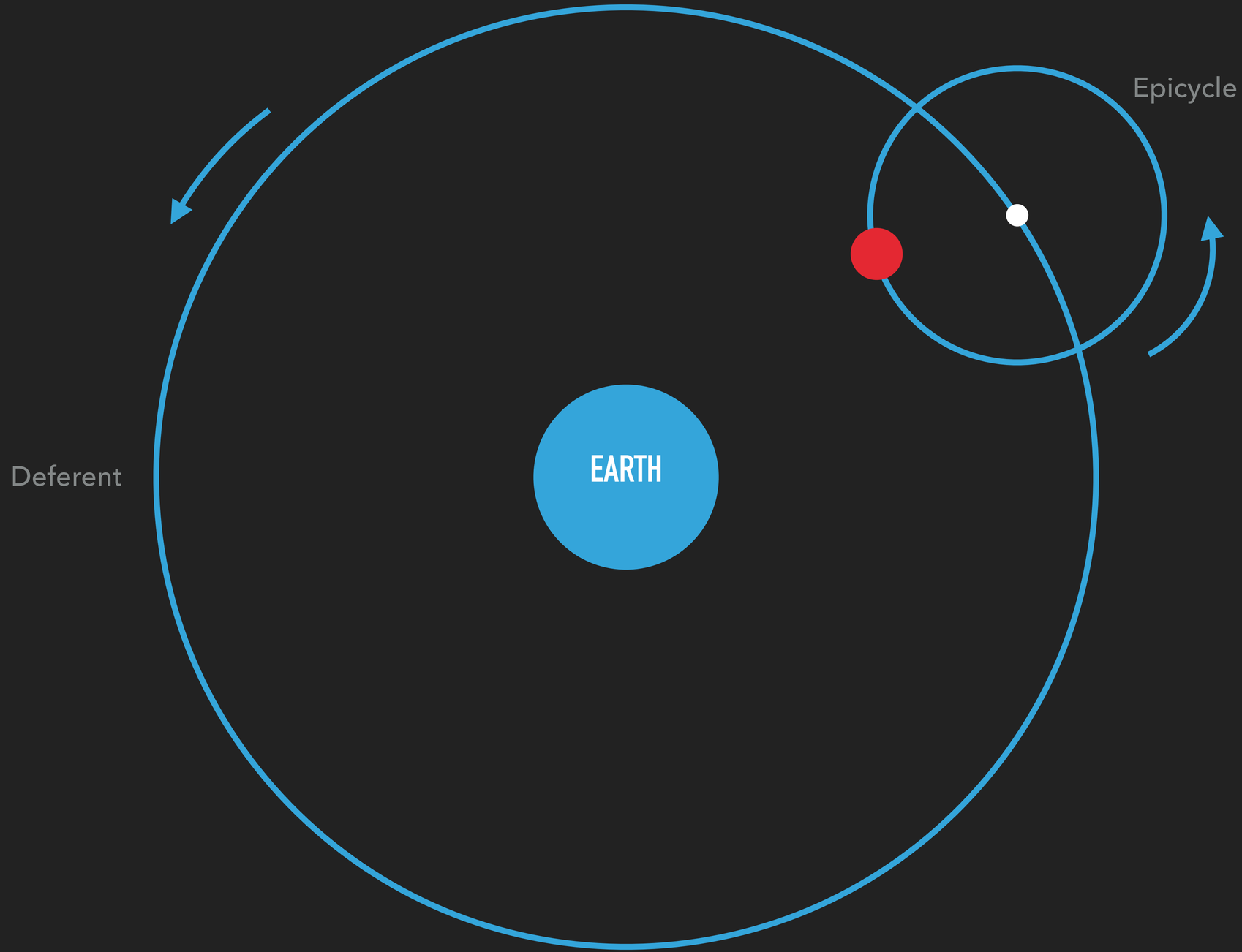
PTOLEMAIC MODEL GEOCENTRIC

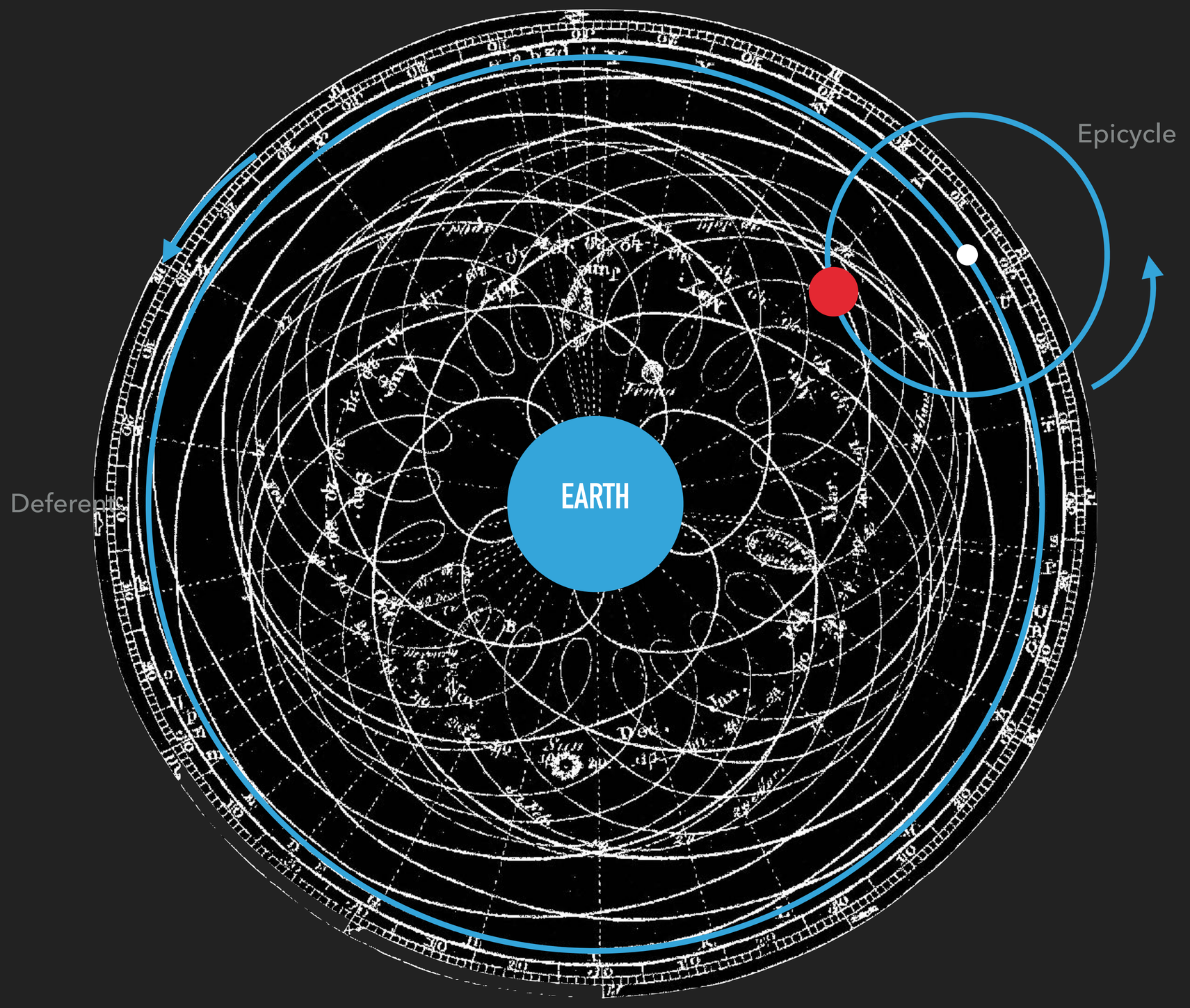


WE'RE THE CENTER OF EVERYTHING

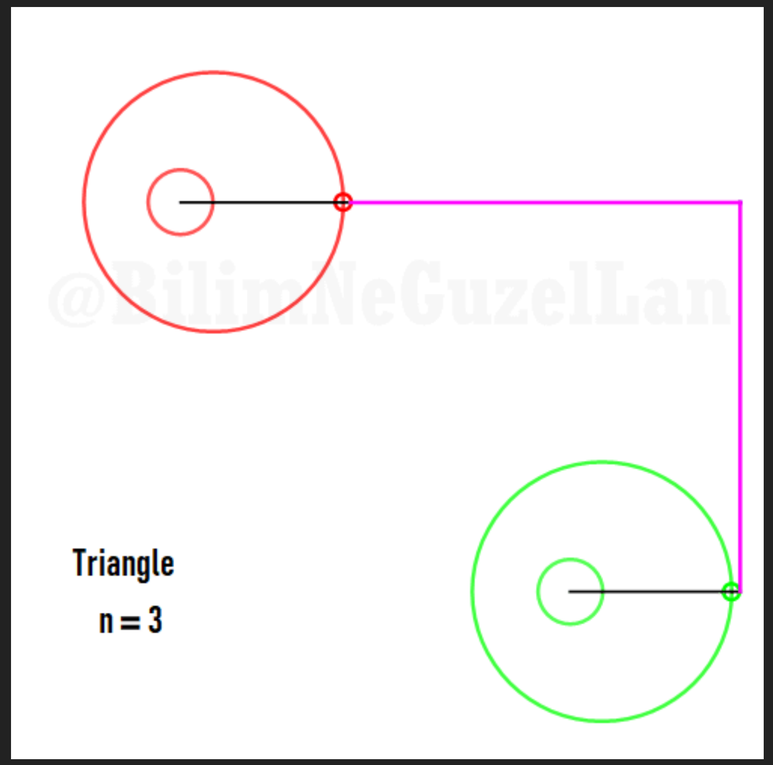
Detailed in the Almagest

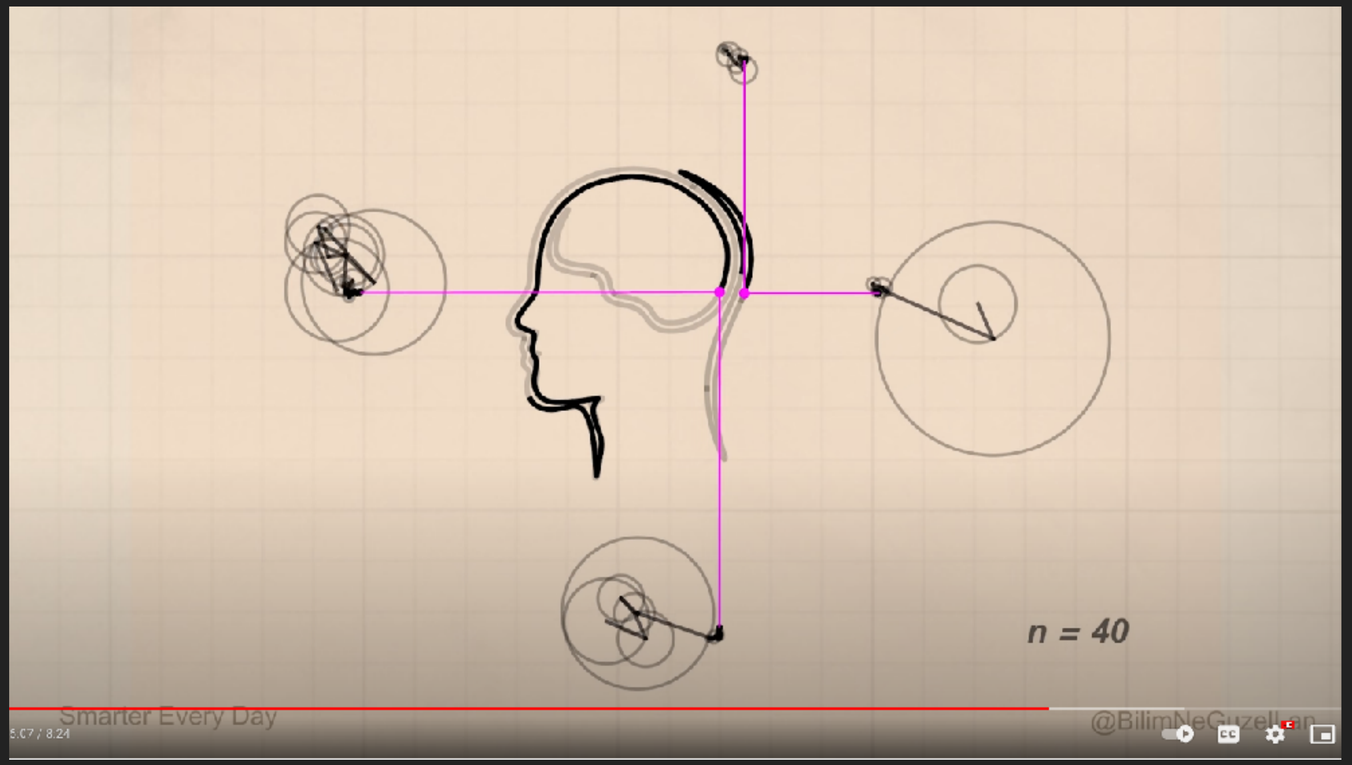
~150BC


Epicycle
Deferent
EARTH


Epicycle
Deferent
EARTH

(ASIDE)





Aside aside: Any shape can be drawn by the composition of the right circles at the right rates. This is a visual equivalent of **Fourier Analysis,** which breaks down a signal (**time domain**) into an infinite sum of pure sine waves of different frequencies (**frequency domain**).

http://bilimneguzellan.net/

https://www.smartereveryday.com/

“PTOLEMY'S UNIVERSE WOULD FIT WITHIN THE ORBIT OF EARTH”

-Calli Arcale, for MentalFloss

ARISTARCHUS OF SAMOS

Heliocentric model, **300BC**

HIPPARCHUS OF NICAEA

Precession of the equinoxes, **150BC**

YU XI (虞喜)

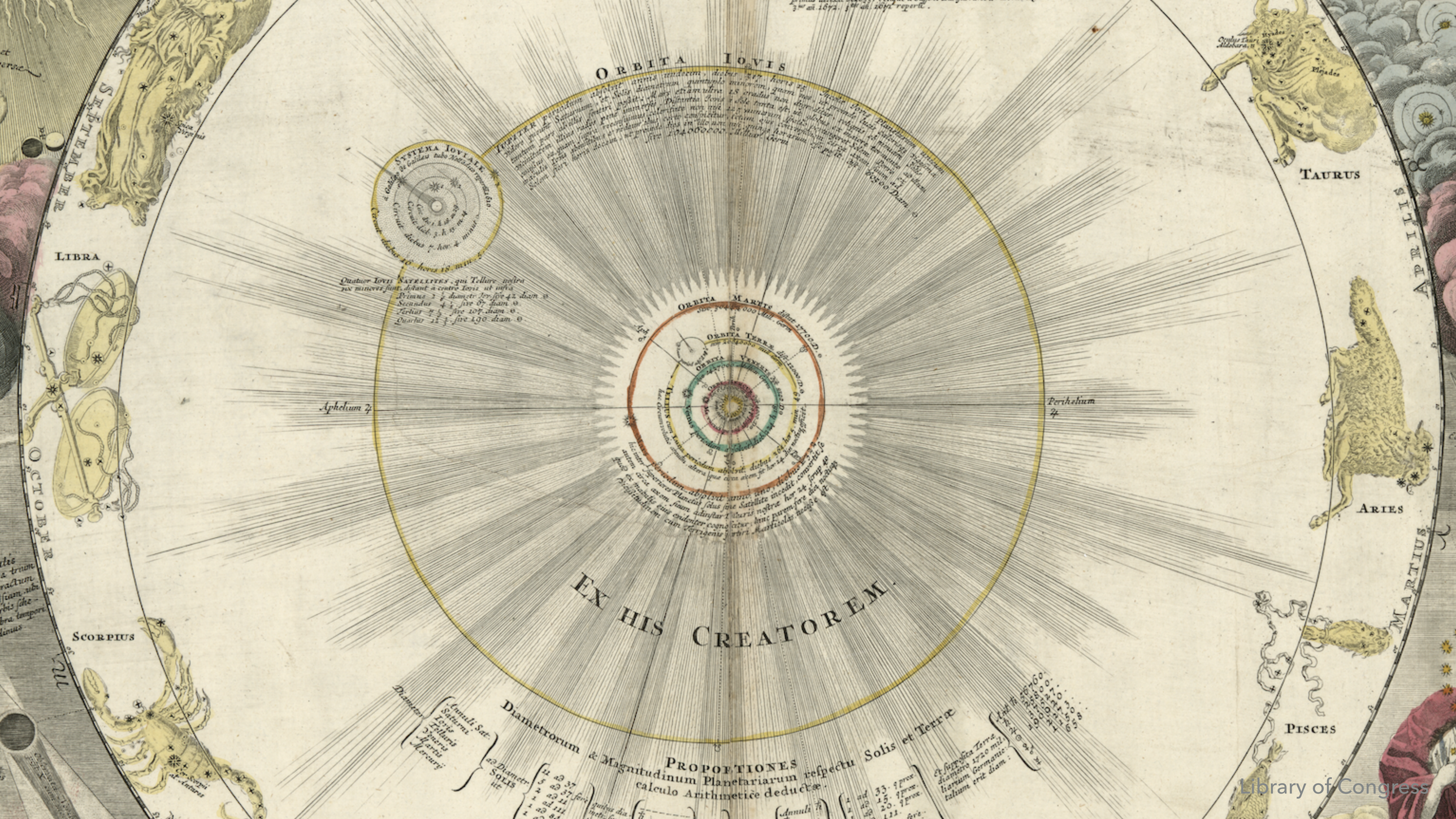
“In **336 AD** Yu Xi wrote the *An Tian Lun* (安天論; *Discussion of Whether the Heavens Are At Rest or Disquisition on the Conformation of the Heavens*).He observed that the position of the sun during the winter solstice had drifted roughly one degree over the course of fifty years relative to the position of the stars.”

-Wikipedia

MARAGHA ASTRONOMERS

“The Maragha school of astronomy in Ilkhanid-era Persia further developed ‘non-Ptolemaic’ planetary models involving Earth's rotation. Notable astronomers of this school are Al-Urdi (d. **1266**) Al-Katibi (d. 1277), and Al-Tusi (d. 1274).”

-Wikipedia



COPERNICAN MODEL

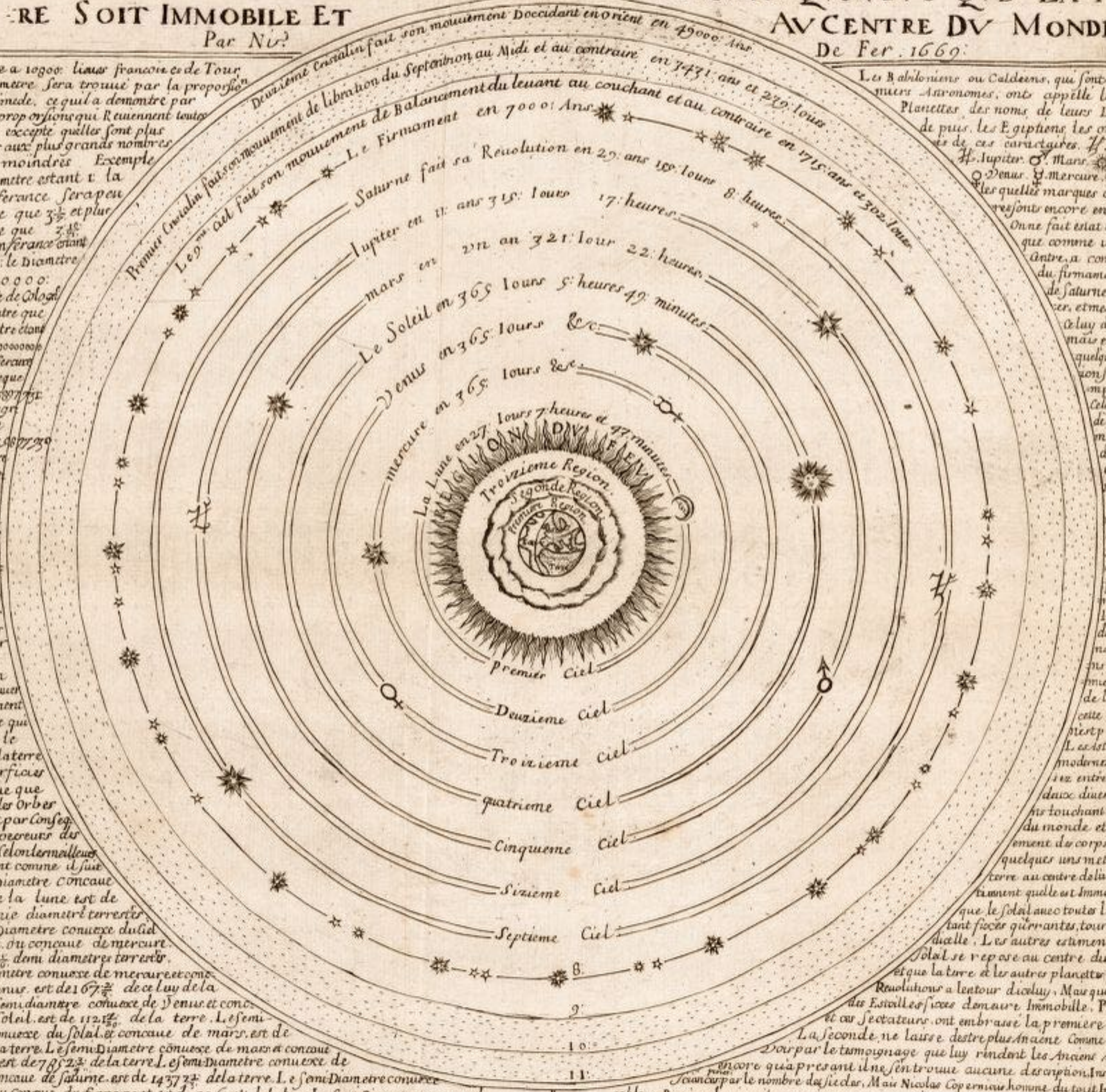
THE SUN IS THE CENTER, BUT WE'RE STILL PRETTY SPECIAL

Detailed in On the Revolutions of the Celestial Spheres

1543CE

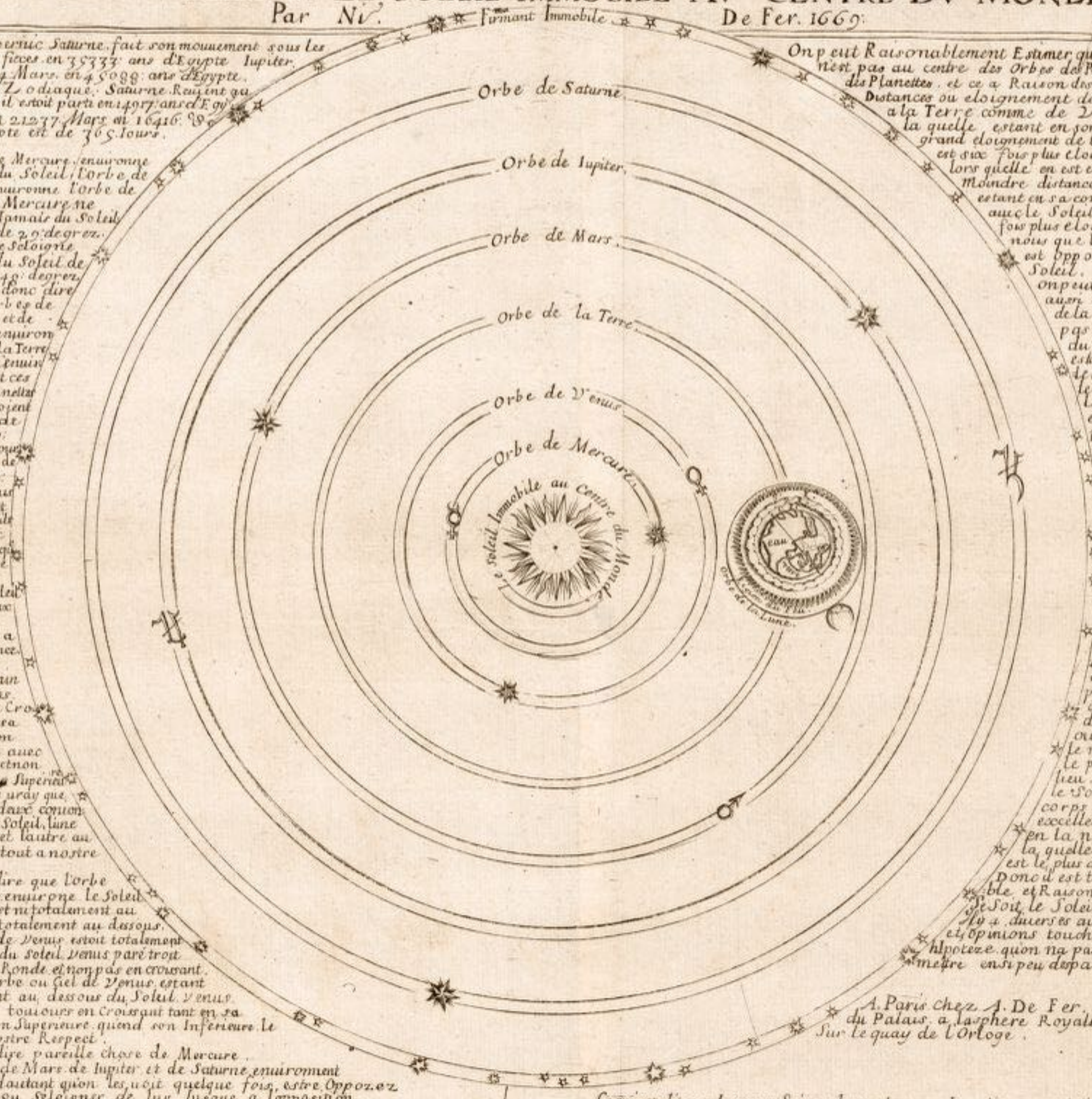
LORDRE DES SPHERES CELESTES SELON PTOLOMEE QUI VEUT QUE LA TERRE SOIT IMMOBILE ET AU CENTRE DU MONDE

Par Nr. De Fer. 1669.



LORDRE DES SPHERES CELESTES SELON COPERNIC QUI TIENT QUE LA TERRE EST MOBILE ET LE SOLEIL IMMOBILE AU CENTRE DU MONDE

Par Nr. De Fer. 1669.

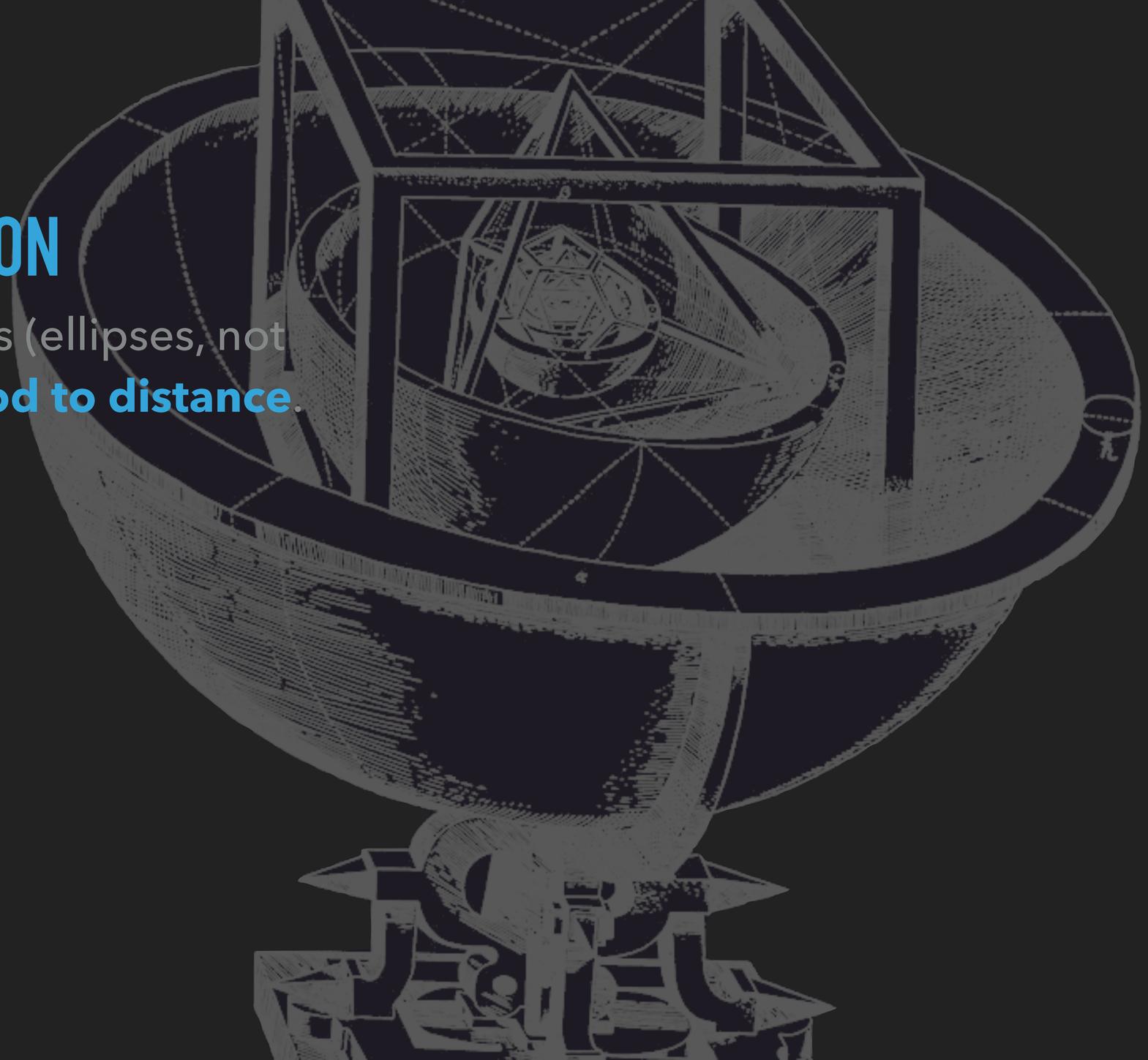


On peut Raisonablement Estimer que la Terre n'est pas au centre des Orbes des Planettes, et ce a Raison des diverses Distances ou eloignement des Planettes a la Terre comme de Venus, la quelle estant en son plus grand eloignement de la Terre est six fois plus eloignee que lors quelle en est en sa moindre distance, et Mars estant en sa conionction auec le Soleil est huit fois plus eloigne de nous que lors quil est Opposez au Soleil.

A Paris chez. N. De Fer. en l'isle du Palais, a la sphere Royalle Sur le quay de l'Orloge.

KEPLER
1609
LAWS OF PLANETARY MOTION

These set the true shape of orbits (ellipses, not circles) and **related orbital period to distance**.



Detailed in Astronomia nova
1609CE

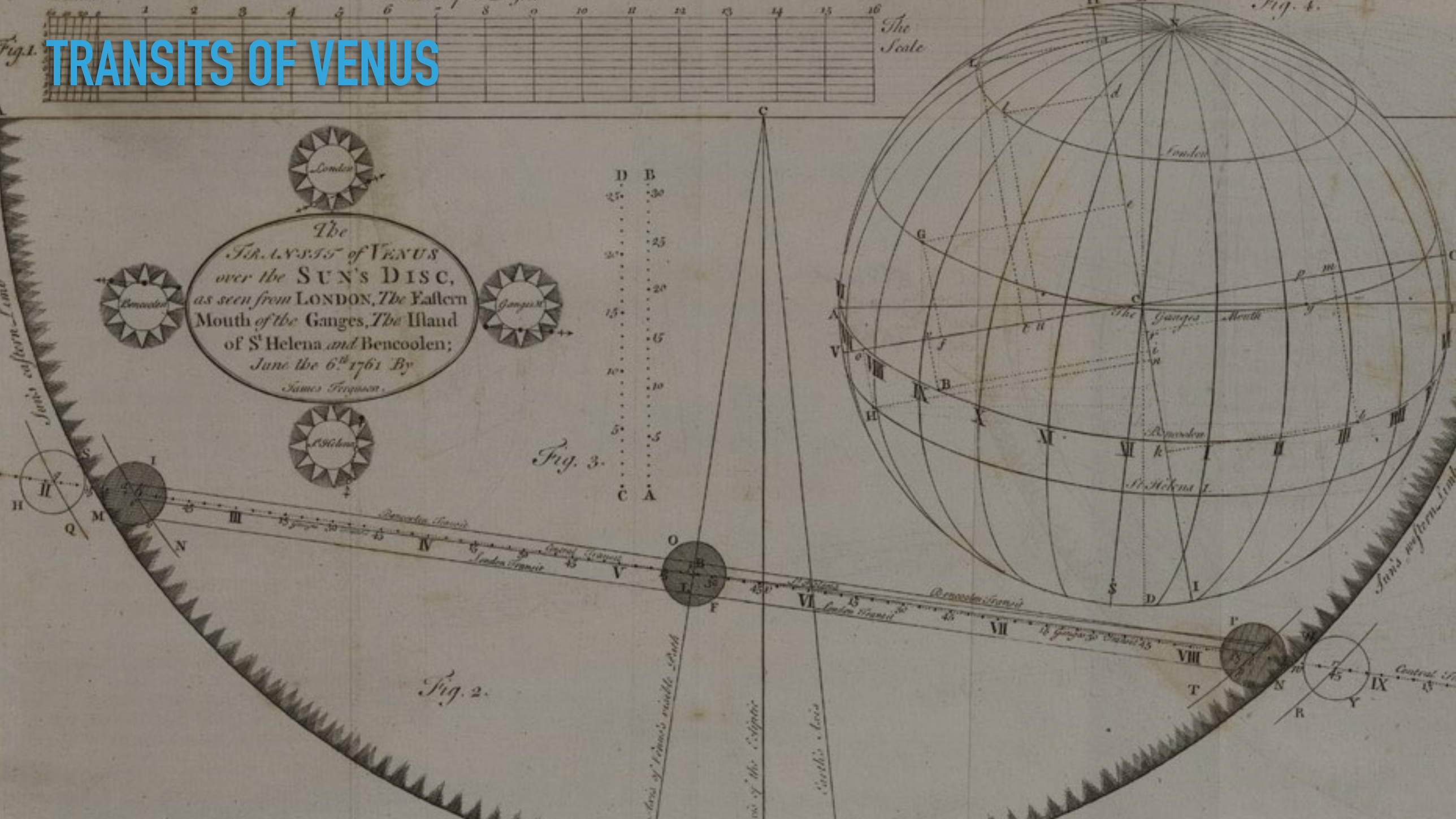
GALILEO
1610–1615
GANYMEDE, CALLISTO, IO, EUROPA

SUNSPOTS

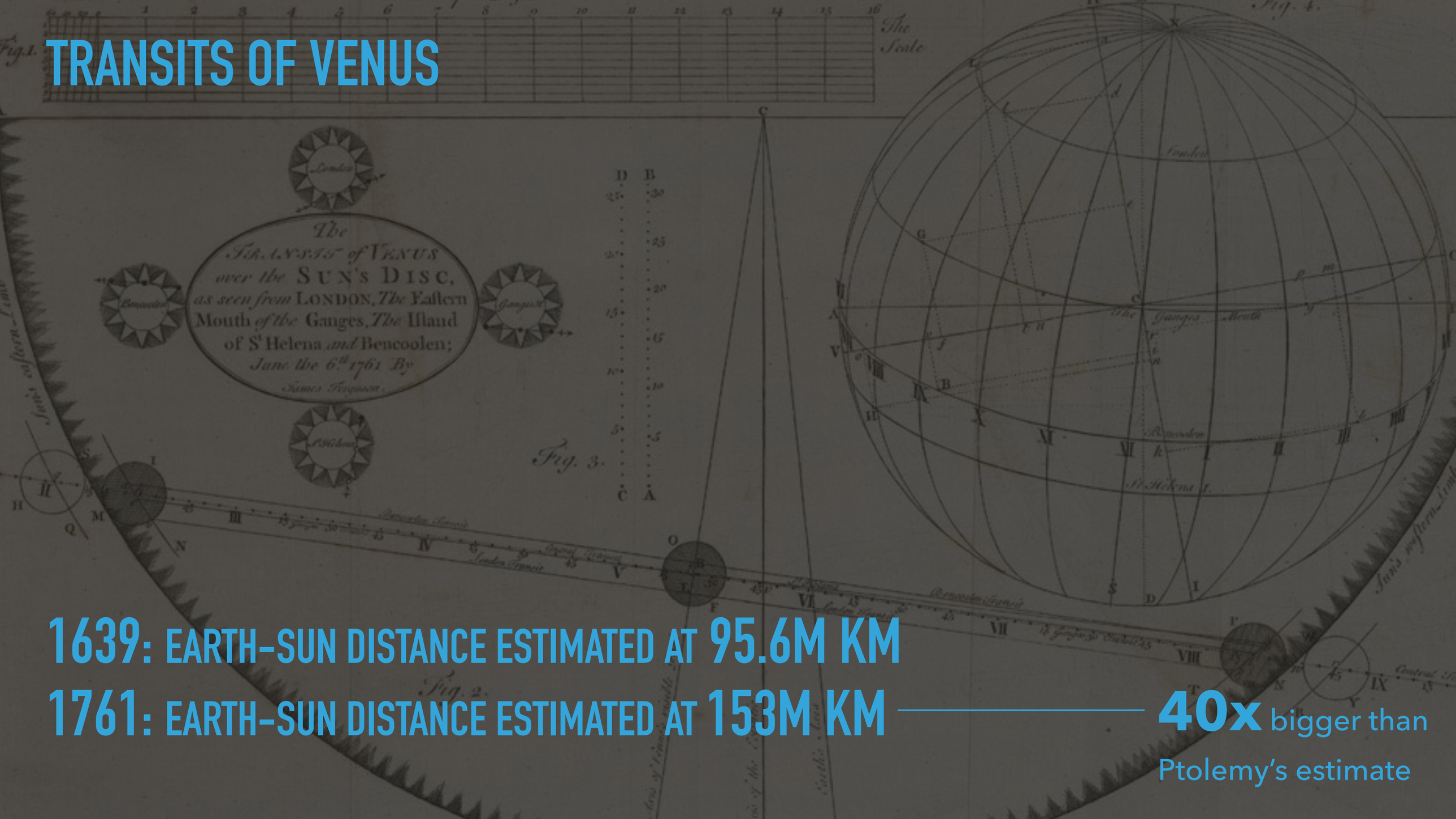
THE SUN IS THE CENTER, AND
WE'RE LESS SPECIAL

Other planets have moons, and
the sun itself rotates

TRANSITS OF VENUS



TRANSITS OF VENUS

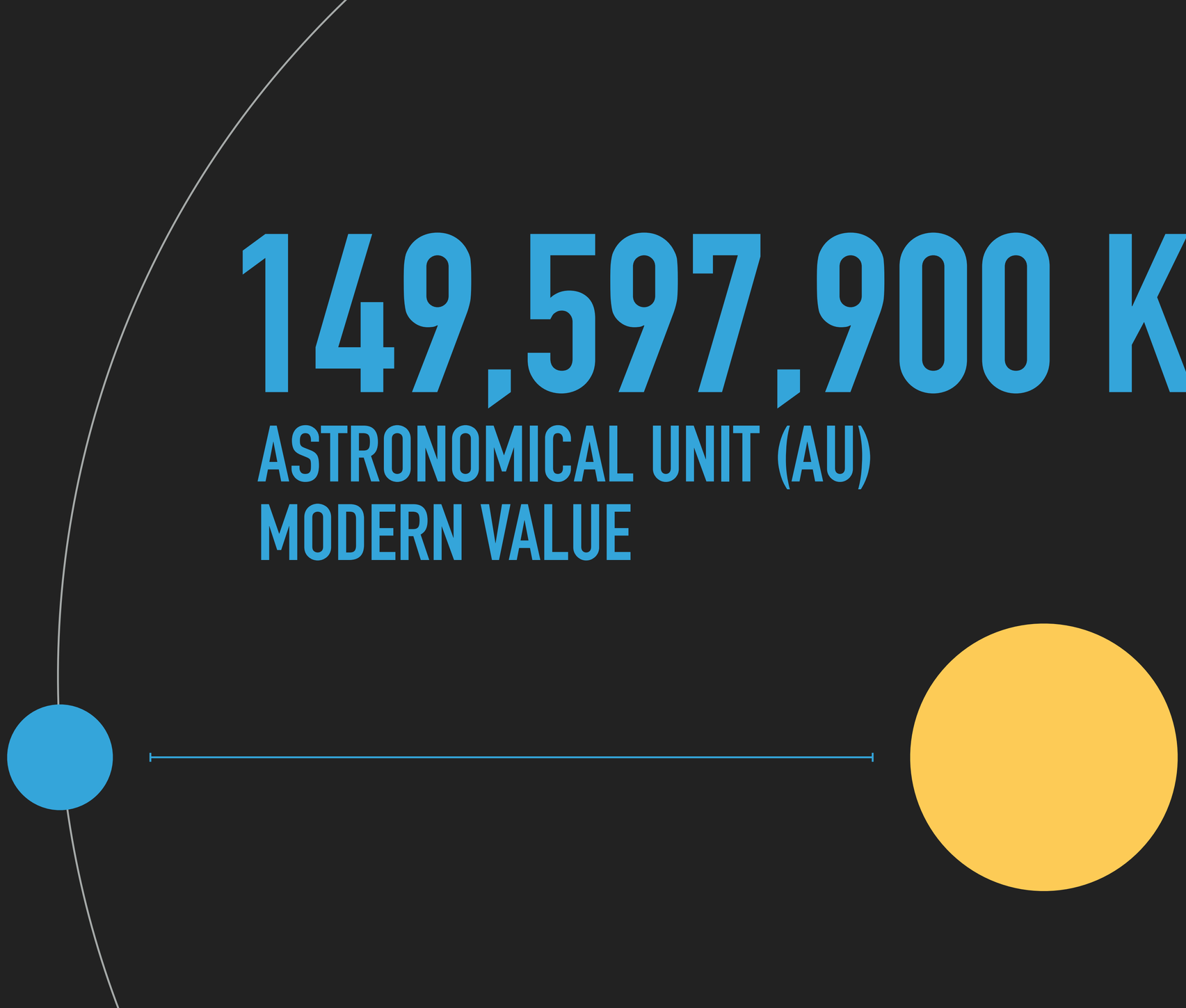


1639: EARTH–SUN DISTANCE ESTIMATED AT 95.6M KM

1761: EARTH–SUN DISTANCE ESTIMATED AT 153M KM — **40x** bigger than Ptolemy's estimate

149,597,900 KM

ASTRONOMICAL UNIT (AU)
MODERN VALUE

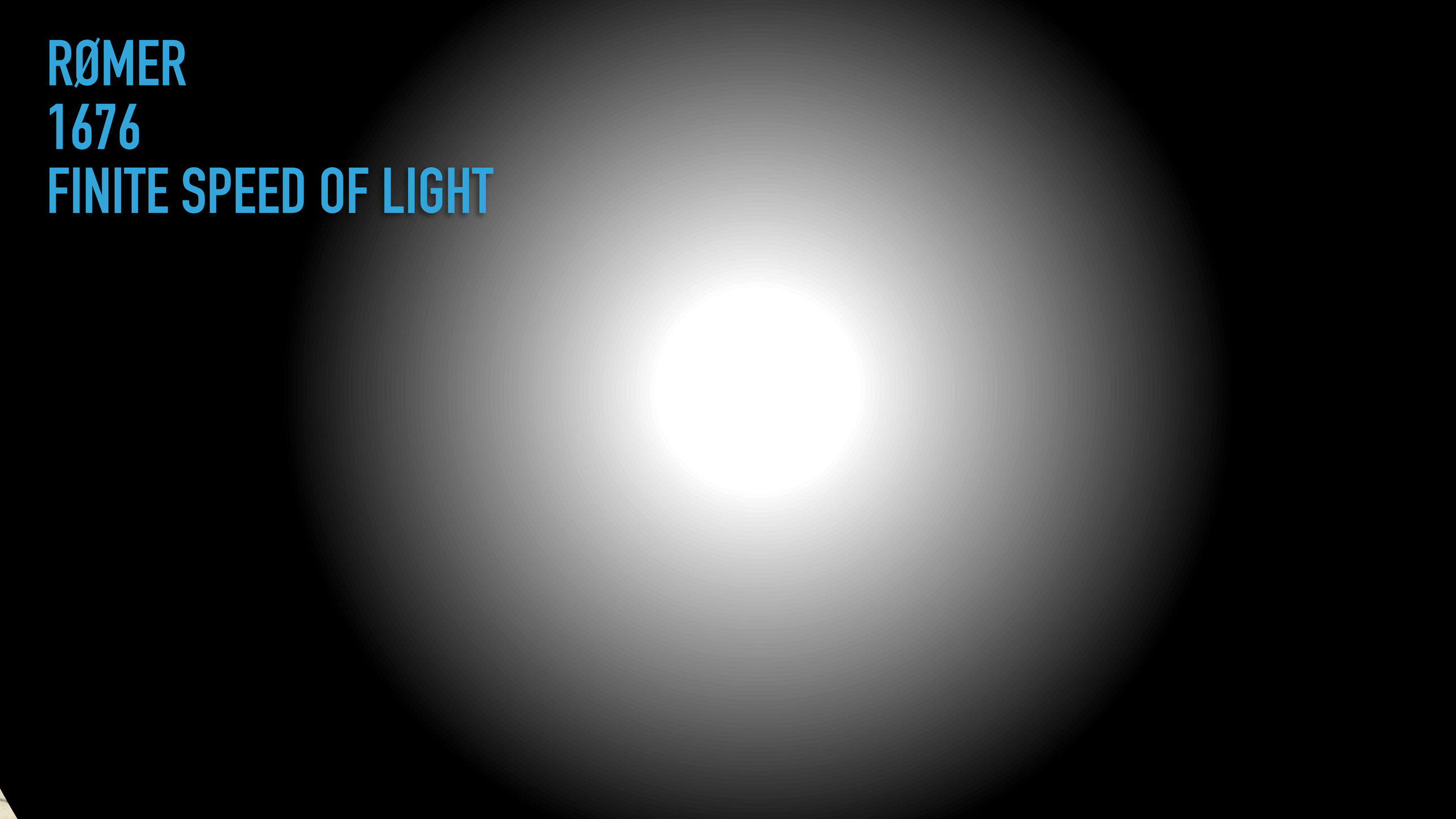


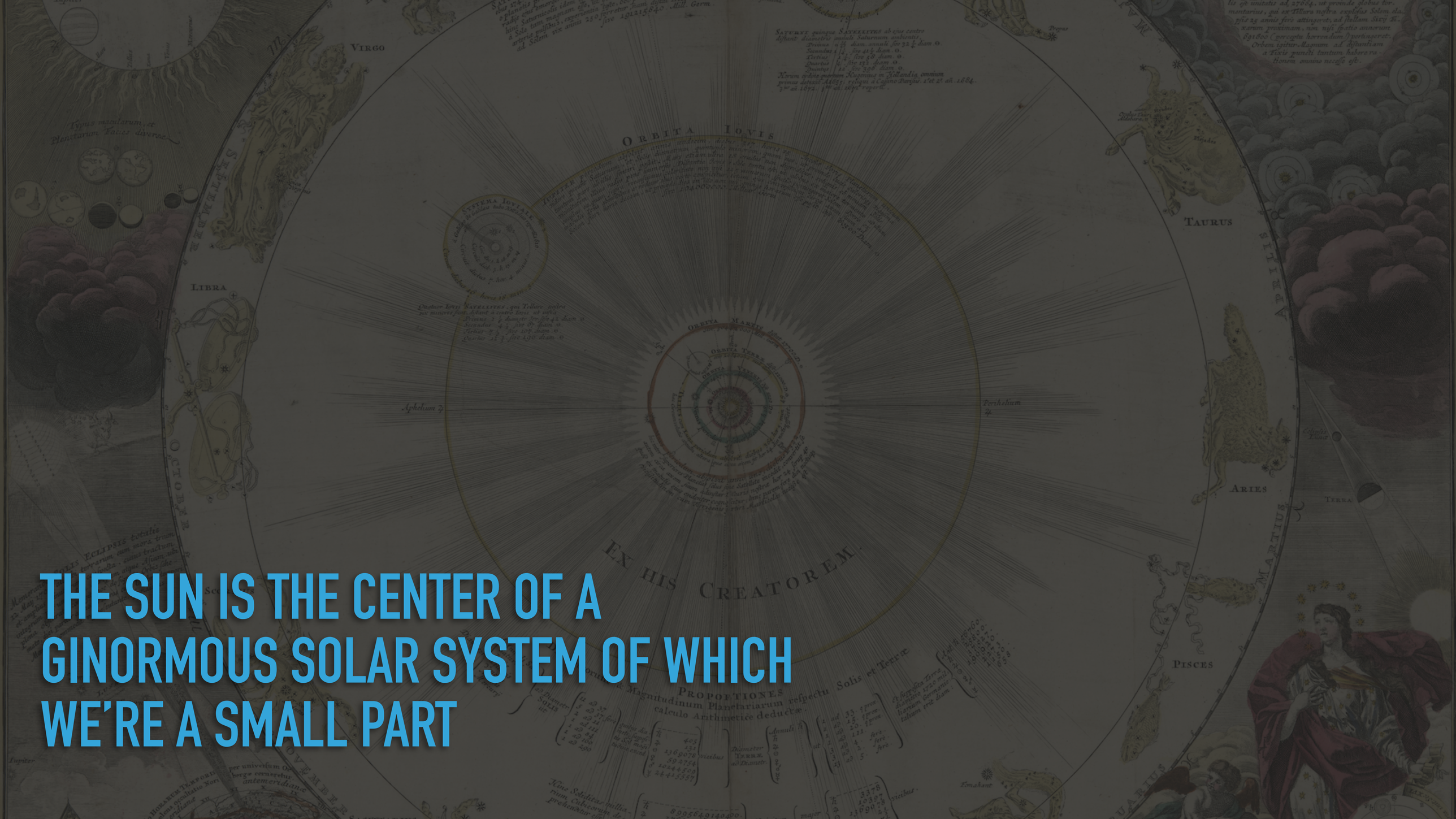
1600s – TITAN AND OTHER MOONS OF SATURN

1700s – MORE PLANETS (URANUS) MORE MOONS (OR URANUS, SATURN)

1800s – CERES, NEPTUNE, THE MOONS OF MARS (PHOBOS AND DEIMOS)

RØMER
1676
FINITE SPEED OF LIGHT

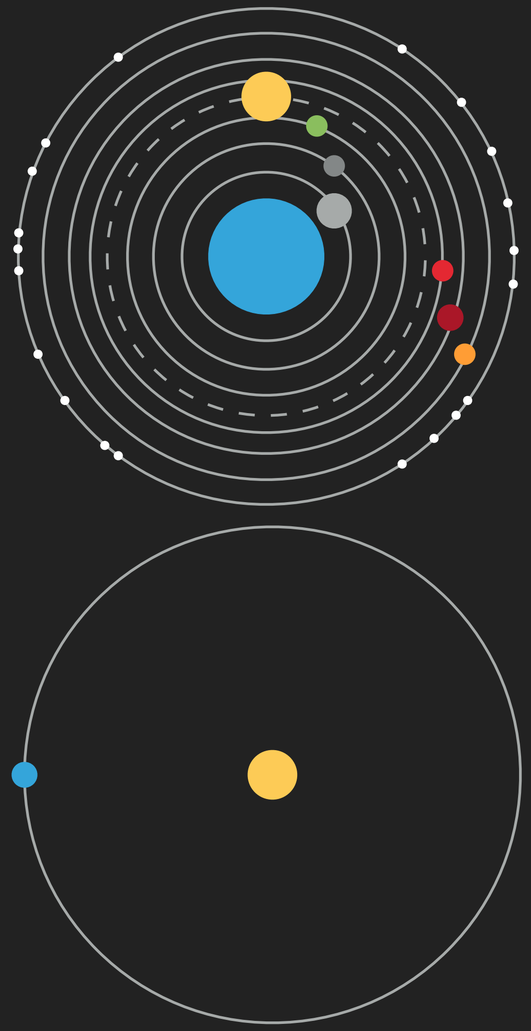


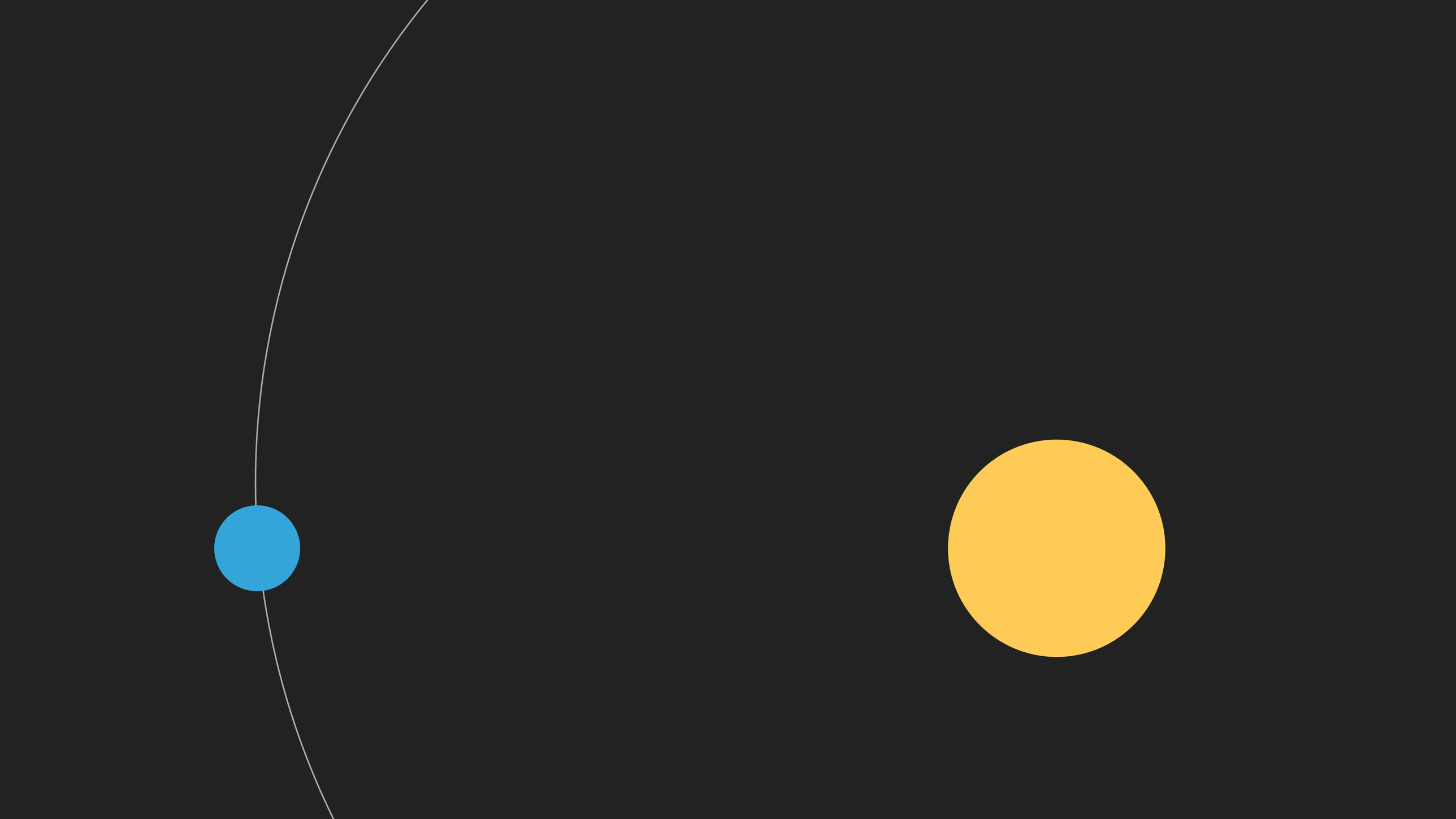


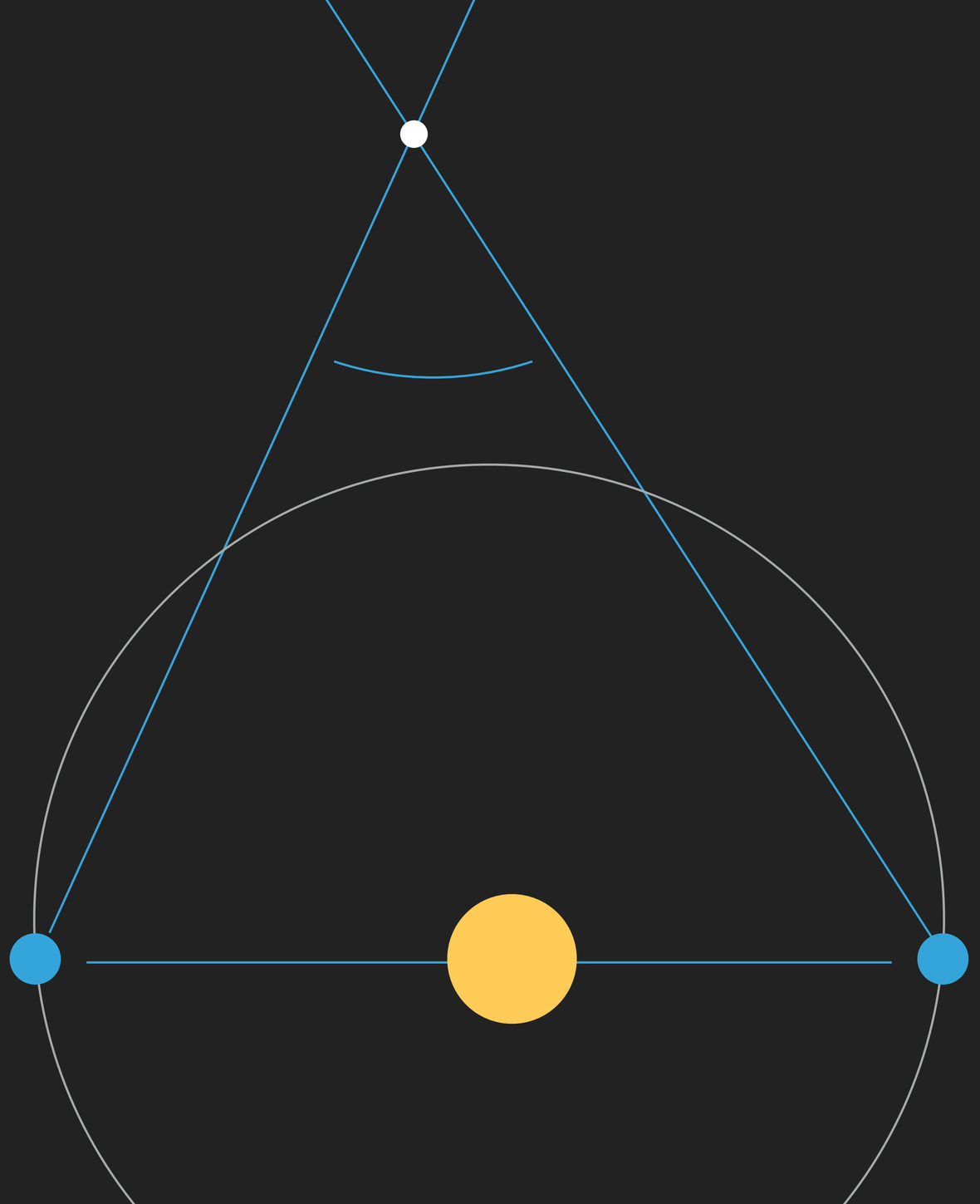
THE SUN IS THE CENTER OF A GINORMOUS SOLAR SYSTEM OF WHICH WE'RE A SMALL PART

“PTOLEMY'S UNIVERSE WOULD FIT WITHIN THE ORBIT OF EARTH”

-Calli Arcale, for MentalFloss

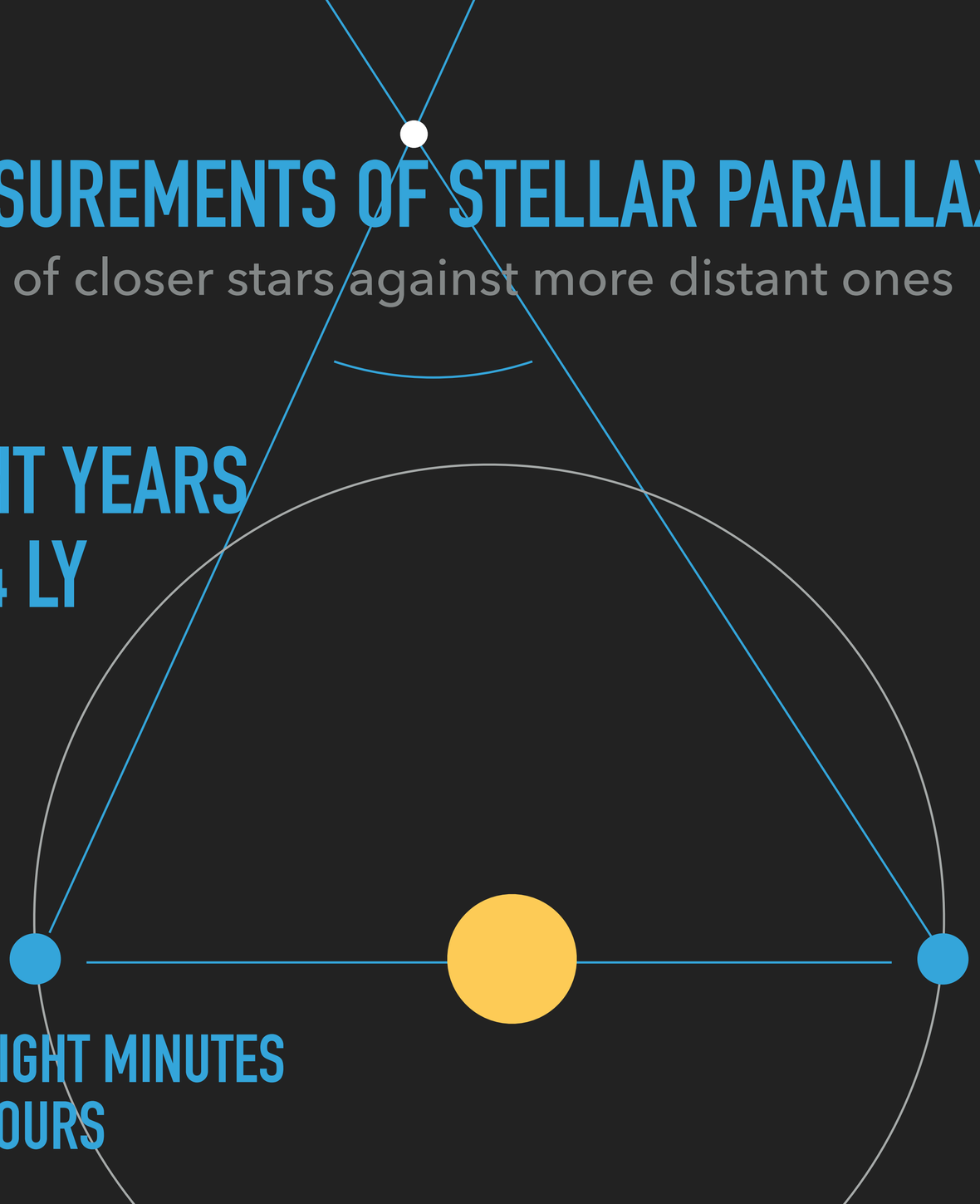






1830s – FIRST MEASUREMENTS OF STELLAR PARALLAX

Apparent seasonal shift of closer stars against more distant ones



CYGNUS : 11.4 LIGHT YEARS
ALPHA CENTAURI: 4 LY

EARTH–SUN DISTANCE: 8 LIGHT MINUTES
SOLAR SYSTEM: 8 LIGHT HOURS

1830s – FIRST MEASUREMENTS OF STELLAR PARALLAX

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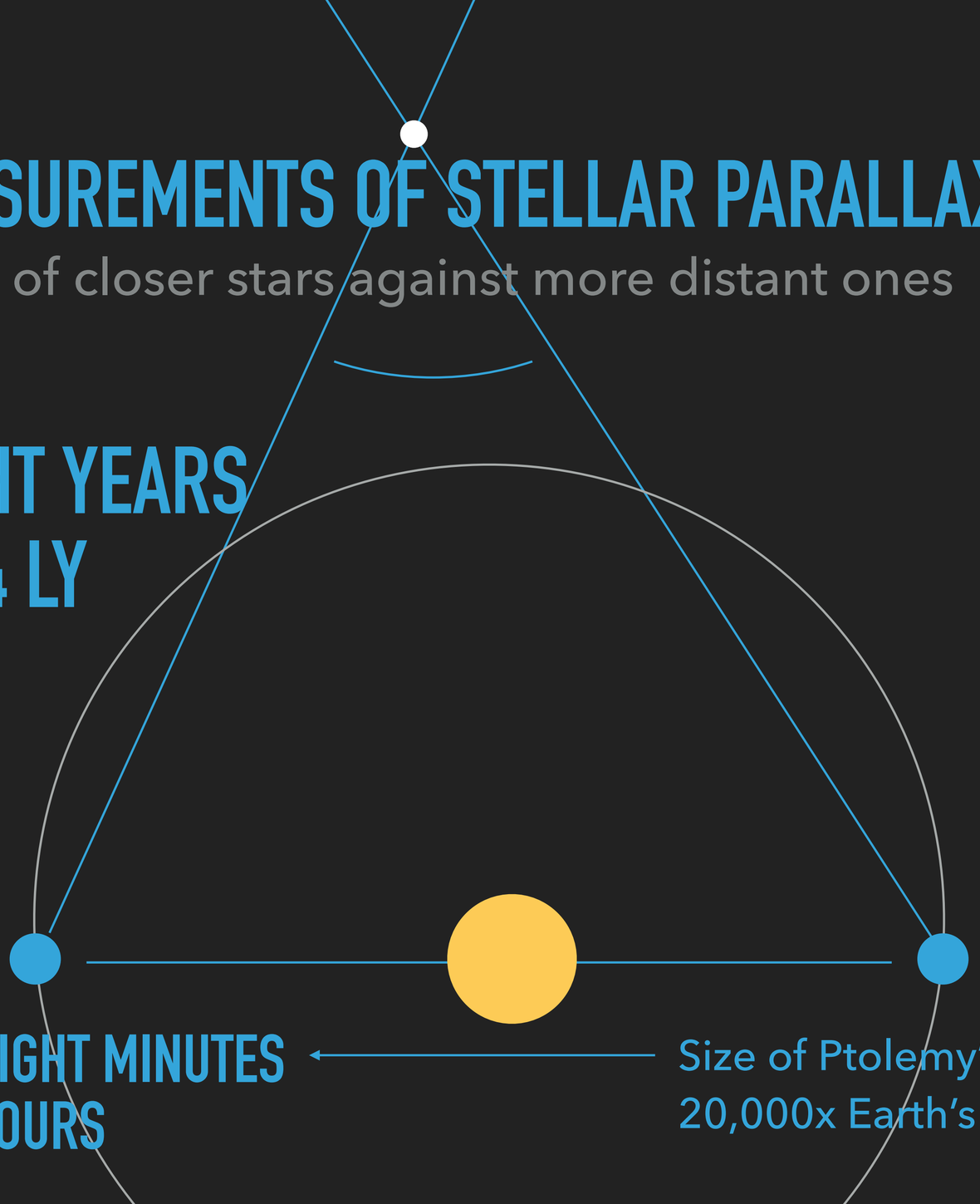


EARTH–SUN DISTANCE: 8 LIGHT MINUTES
SOLAR SYSTEM: 8 LIGHT HOURS

Size of Ptolemy’s Entire Celestial Sphere:
20,000x Earth’s radius ~= 7 light minutes

EARLY 1900S

Parallax method maps thousands of the nearest stars (within **100ly**). Correlations between brightness, spectrum, and distance allow us to infer position of more distant stars within this galaxy*, up to about **300ly**.

Milky Way galaxy is ~100,000 light years across, so we're well within our own universe.

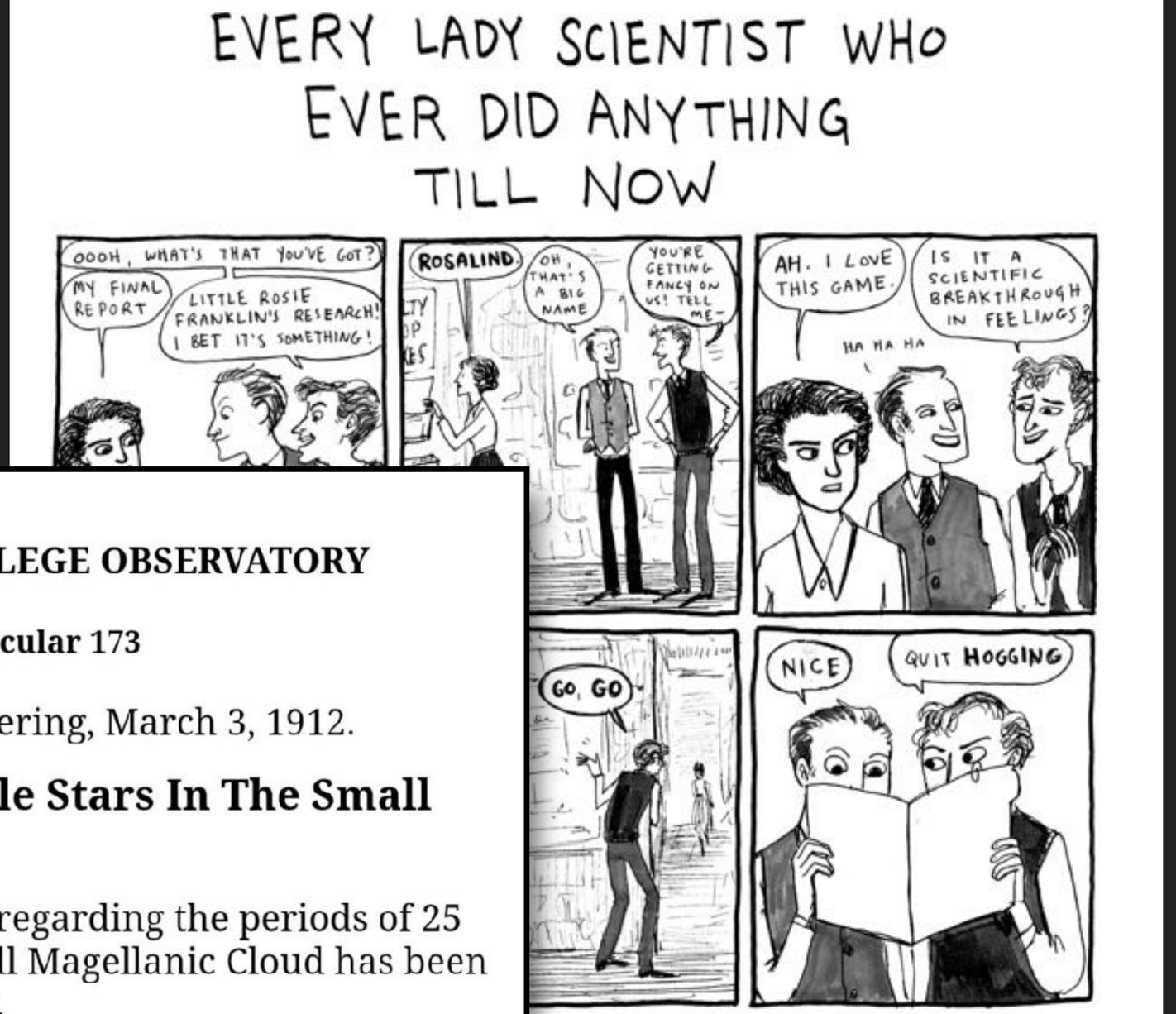
When Einstein published his first relativity paper, ***it was not known if the universe consisted of more than our local galaxy****.*

https://www.youtube.com/watch?v=2FrY6gRPC7k

EVERY LADY SCIENTIST WHO EVER DID ANYTHING TILL NOW

Rosalind! Don't let 'em get you down. The trouble with reading about any given woman who was born before your mom is that yes, sometimes, they were hilarious, powerful, tough, loud, etcetera, etcetera—all good comic making material! But then sometimes, man, the main thing about them is that they just got screwed, big time. Here's to all the old time ladies of science, and their ideas that were worth stealing.

Kate Beaton
http://www.harkavagrant.com



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HARVARD COLLEGE OBSERVATORY

Circular 173

Edward C. Pickering, March 3, 1912.

Periods Of 25 Variable Stars In The Small Magellanic Cloud.

The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt.

A Catalogue of 1777 variable stars in the two Magellanic Clouds is given in H.A. 60, No. 4. The measurement and discussion of these objects present problems of unusual difficulty, on account of the large

Kate Beaton
http://www.harkavagrant.com

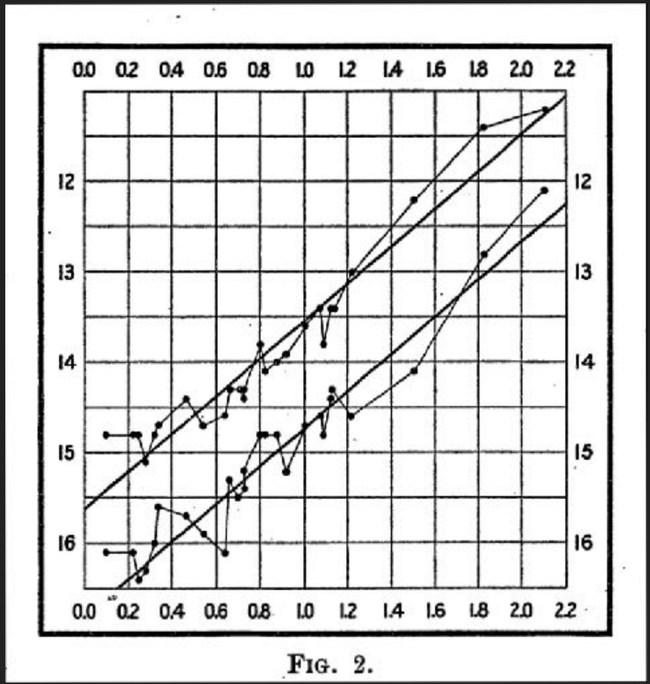


FIG. 2.

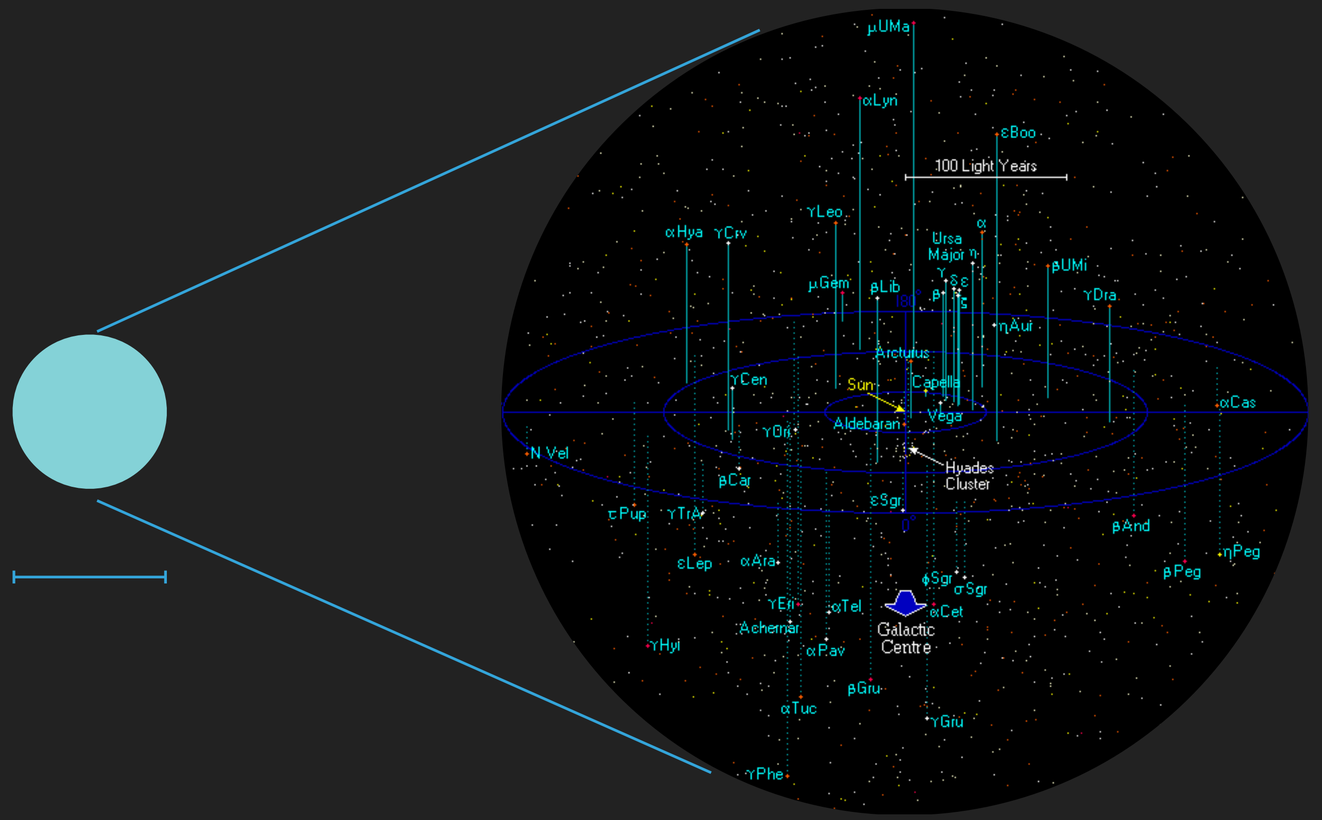
LEAVITT'S LAW (1908)

Leavitt, not permitted direct telescope time, instead analyzed photographic plates as a Harvard "computer", and discovered a correlation between the period of a special pulsating star, known as a Cepheid Variable, with its brightness.

This established the first "standard candle", allowing astronomers to distinguish bright distant stars from dim nearby ones.

Leavitt's law allowed determining stellar distance up to 60,000,000 light years.

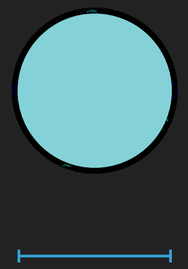
up from 300ly!!



250,000+ stars

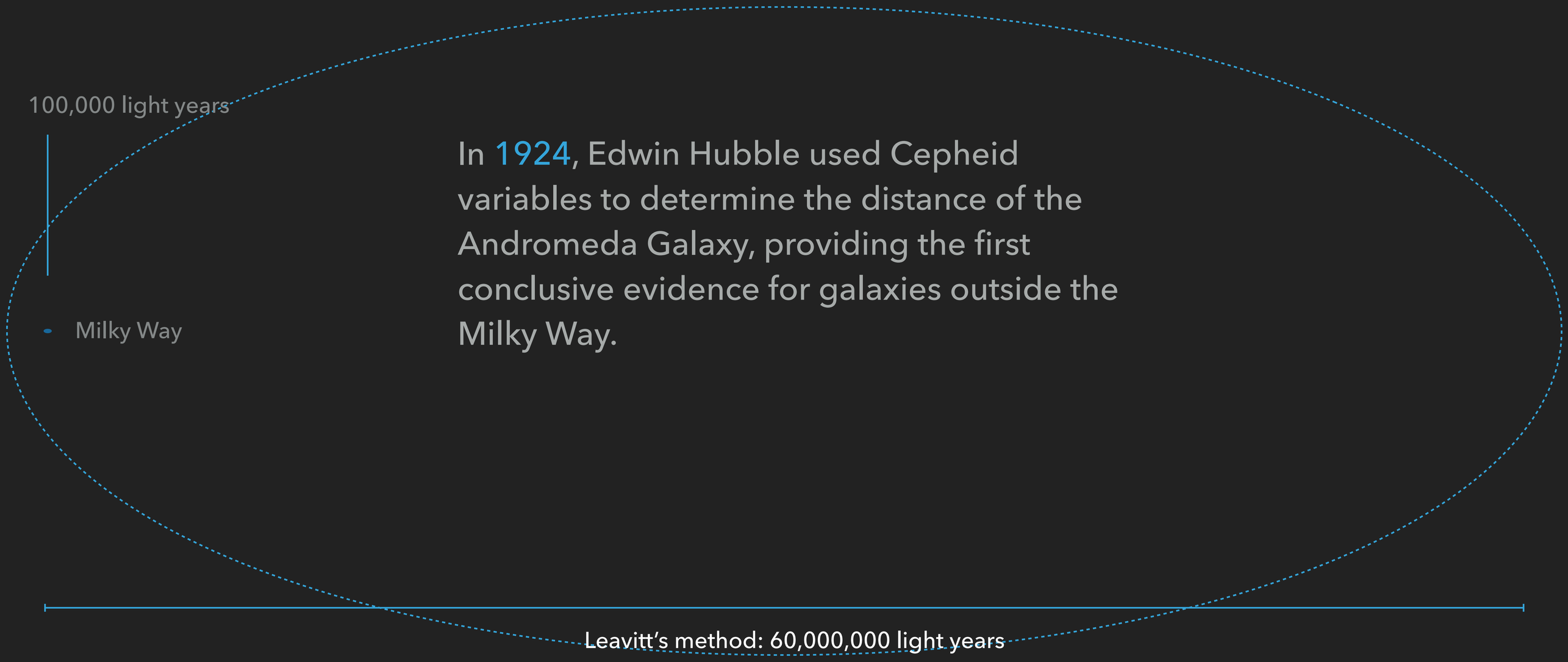
1/3 of stars visible to the naked eye

Parallax method: 300 light years

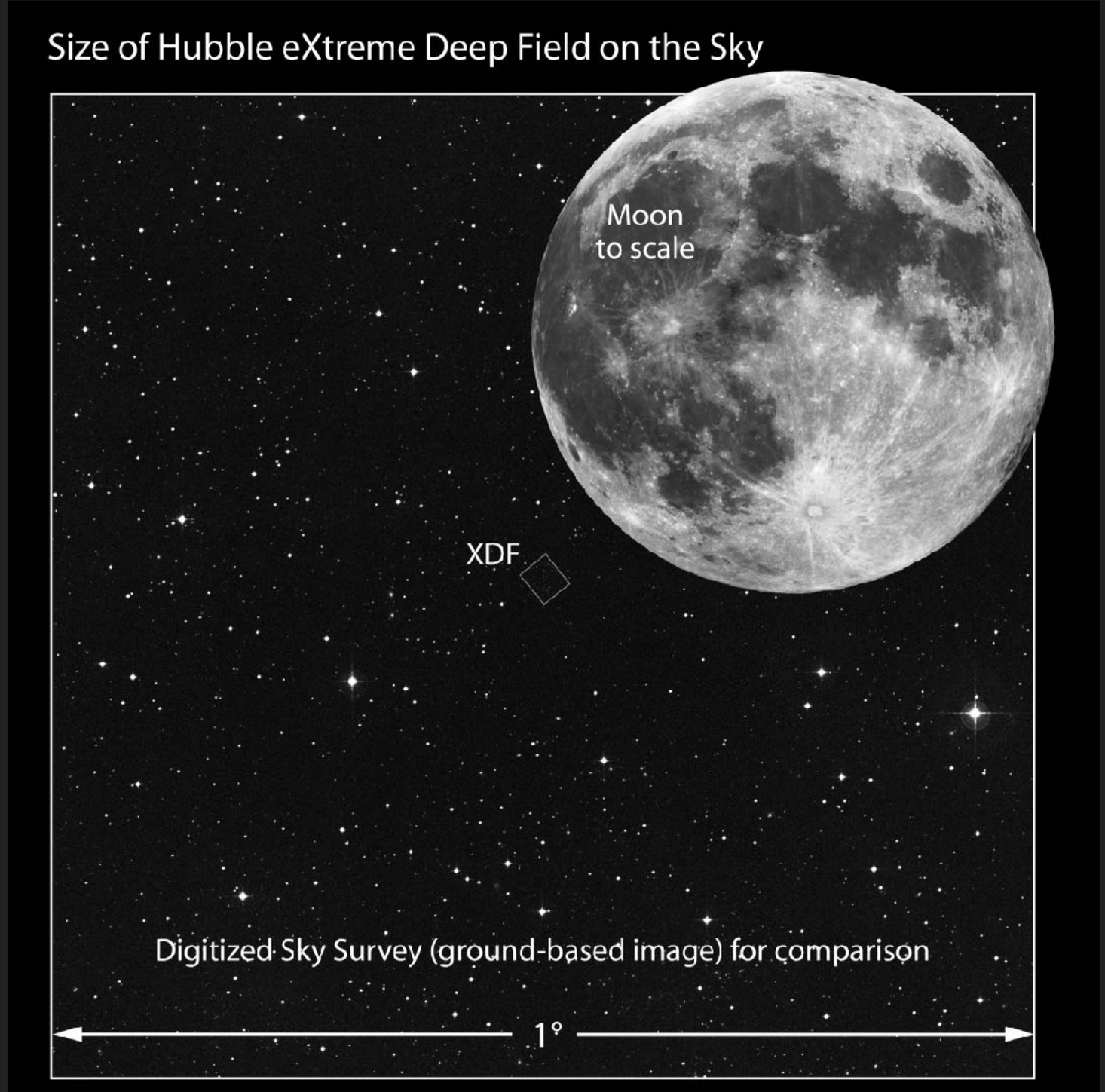


Parallax method: 300 light years


300 light years
100 billion to 400 billion stars
Milky Way Galaxy: 100,000 light years


100,000 light years
Milky Way
In 1924, Edwin Hubble used Cepheid variables to determine the distance of the Andromeda Galaxy, providing the first conclusive evidence for galaxies outside the Milky Way.
Leavitt’s method: 60,000,000 light years

HUBBLE DEEP FIELD



NASA

HUBBLE DEEP FIELD

https://www.nasa.gov/

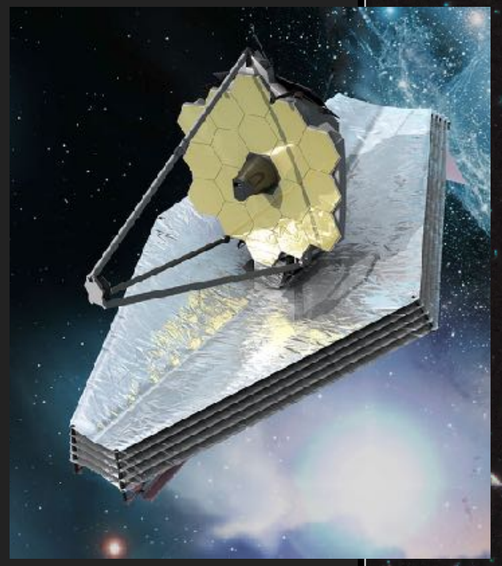
HUBBLE DEEP FIELD

"The XDF is the deepest image of the sky ever obtained and reveals the faintest and most distant galaxies ever seen. XDF allows us to explore further back in time than ever before"*

—principal investigator of the Hubble Ultra Deep Field.

https://www.nasa.gov/

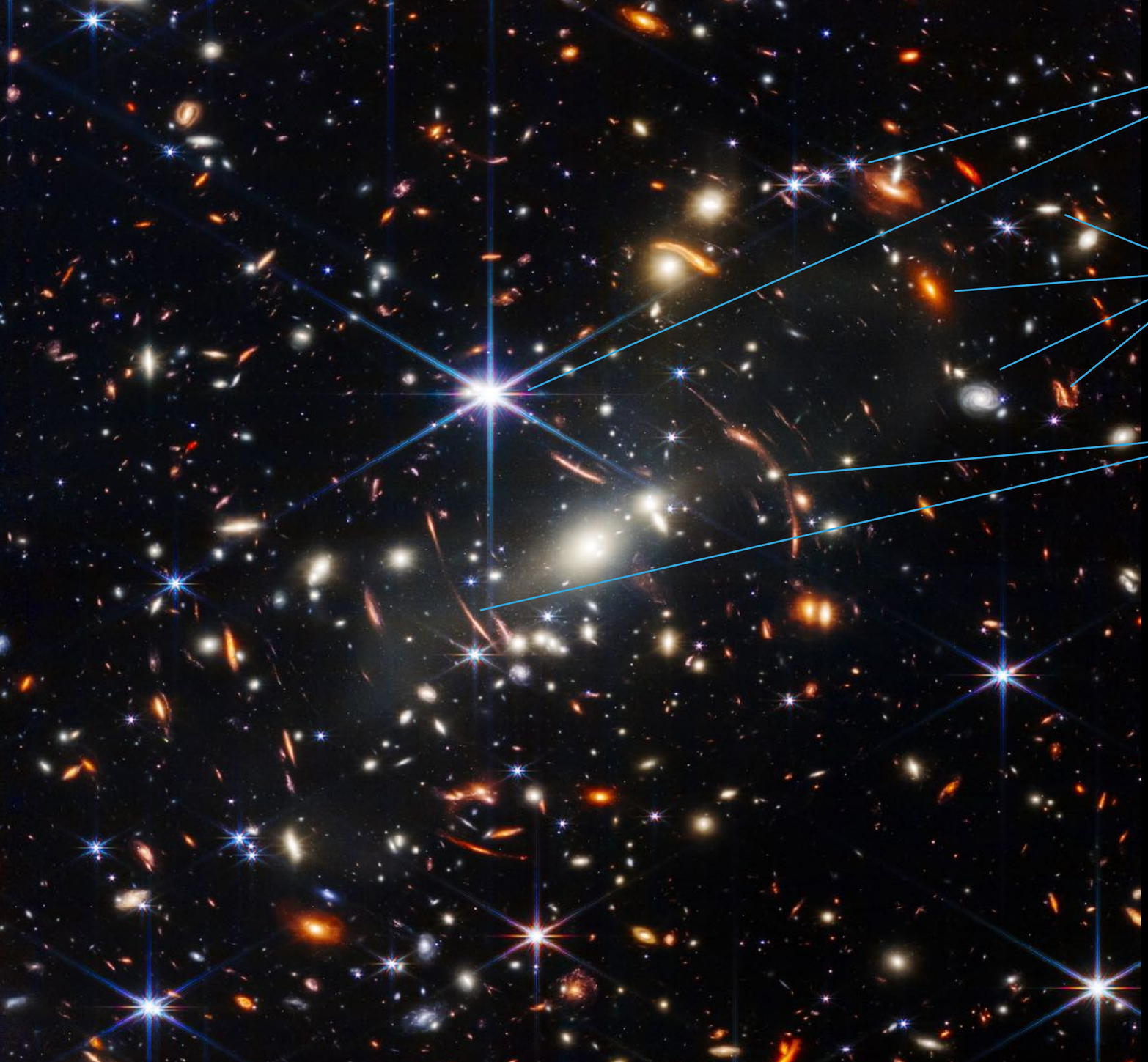
HUBBLE DEEP FIELD



*Until now…

Hubble/JWT comparison (simulated JWT images)

https://newatlas.com/james-webb-space-telescope



Nearby local Mikly Way stars have 8 light spikes due to lens support mechanism (like bokeh)

Everything else is a GALAXY!! Each of which might contain billions or even trillions of stars.

These galaxies are distorted in a ring shape because of gravitational lensing. They are behind the super-massive galactic cluster SMACS 0723 in the center of the image.

It took 12.5 hours to gather the images in this composite. It took weeks of exposure time over a year to create the Hubble Deep Field image.

Some of the light that formed this image is over **13 billion years old**.

If you held a grain of sand at arms length, it would cover up this portion of sky.

https://www.fi.edu/blog/First-JMST-Image
https://www.nasa.gov/webbfirstimages

1929

Hubble uses Cepheid distances to determine the **Universe is expanding**. This leads to the concept of the Big Bang and an age to the Universe.

1998

Researchers using methods similar to Leavitt's applied to supernovae (finding 'standard candles') determine the **expansion of the Universe is accelerating.**


Image: Carlos Budassi

DRAKE EQUATION

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

The number of civilisations in our galaxy in which communication might be possible.

The fraction of stars with planets

The fraction that can go on to support intelligent life.

Length of time such civilisations release detectable signs into space.

The average rate of star formation per year in our galaxy

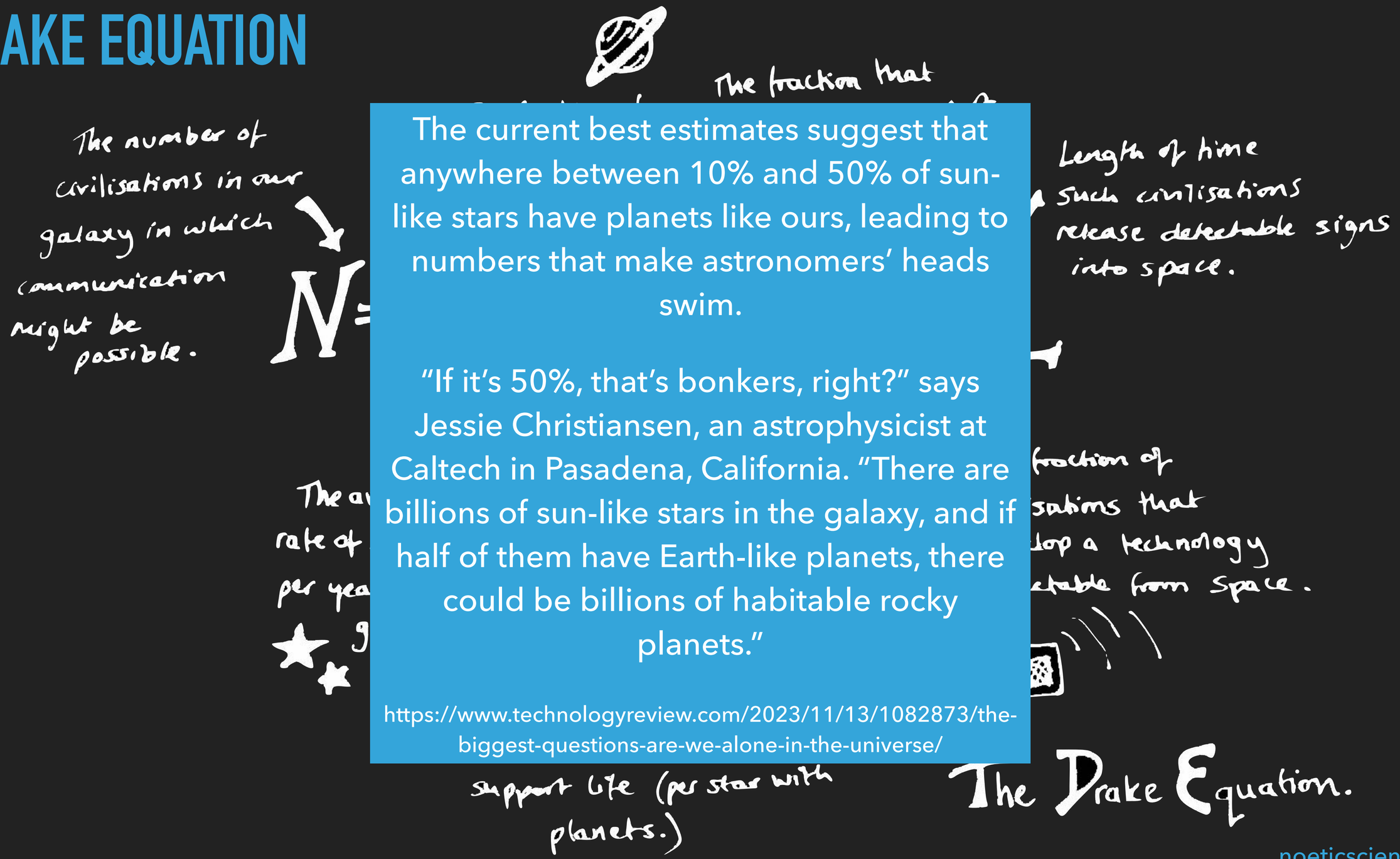
The average number of planets that can potentially support life (per star with planets.)

The fraction that can go on to support life.

The fraction of civilisations that develop a technology detectable from space.

The Drake Equation.

DRAKE EQUATION



The current best estimates suggest that anywhere between 10% and 50% of sun-like stars have planets like ours, leading to numbers that make astronomers' heads swim.

"If it's 50%, that's bonkers, right?" says Jessie Christiansen, an astrophysicist at Caltech in Pasadena, California. "There are billions of sun-like stars in the galaxy, and if half of them have Earth-like planets, there could be billions of habitable rocky planets."

https://www.technologyreview.com/2023/11/13/1082873/the-biggest-questions-are-we-alone-in-the-universe/

DRAKE EQUATION

Astronomers estimate that the universe could contain up to one septillion stars – which in numbers is 1,000,000,000,000,000,000,000,000.

Our Milky Way alone contains more than 100 billion.

https://universe.nasa.gov/stars/basics/

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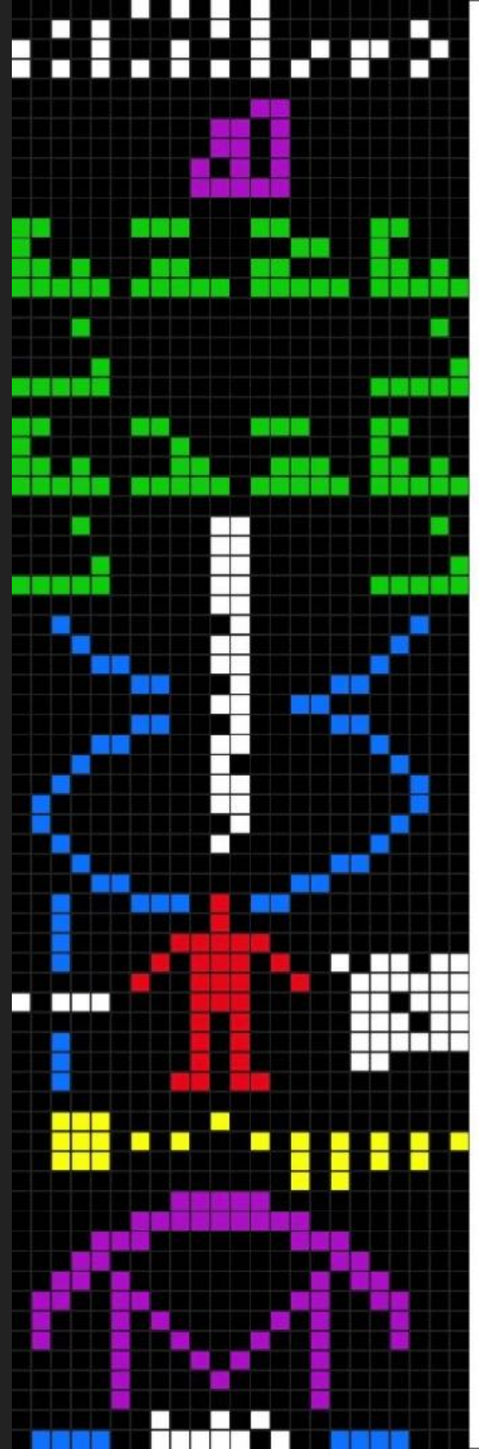
ARECIBO MESSAGE

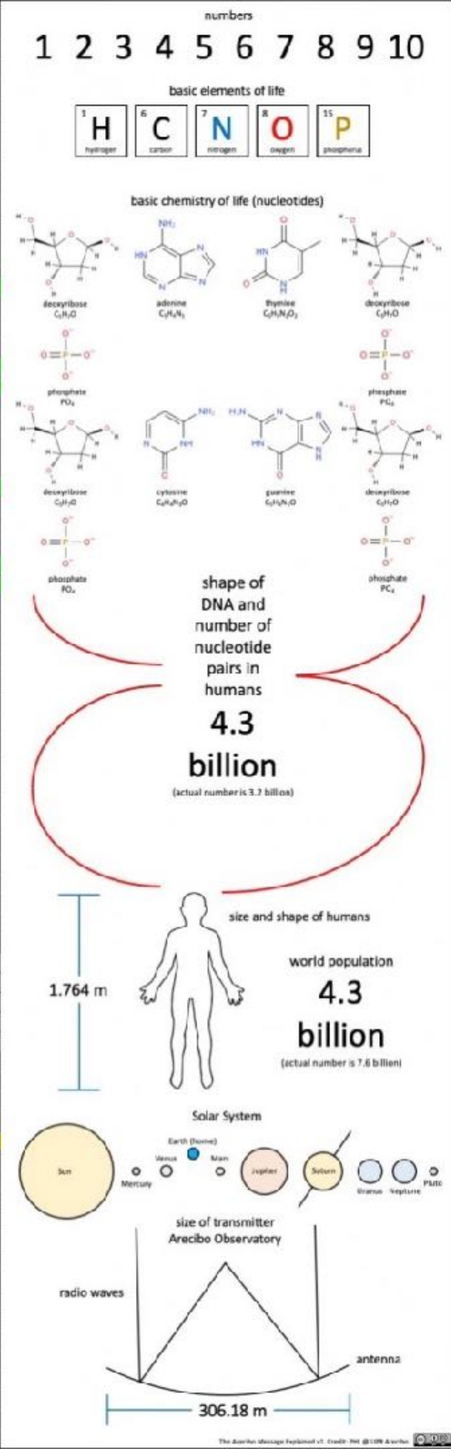
Designed by Frank Drake.

Beamed towards Messier 13 Supercluster in 1974.

Messier 13 is 25,000 ly away

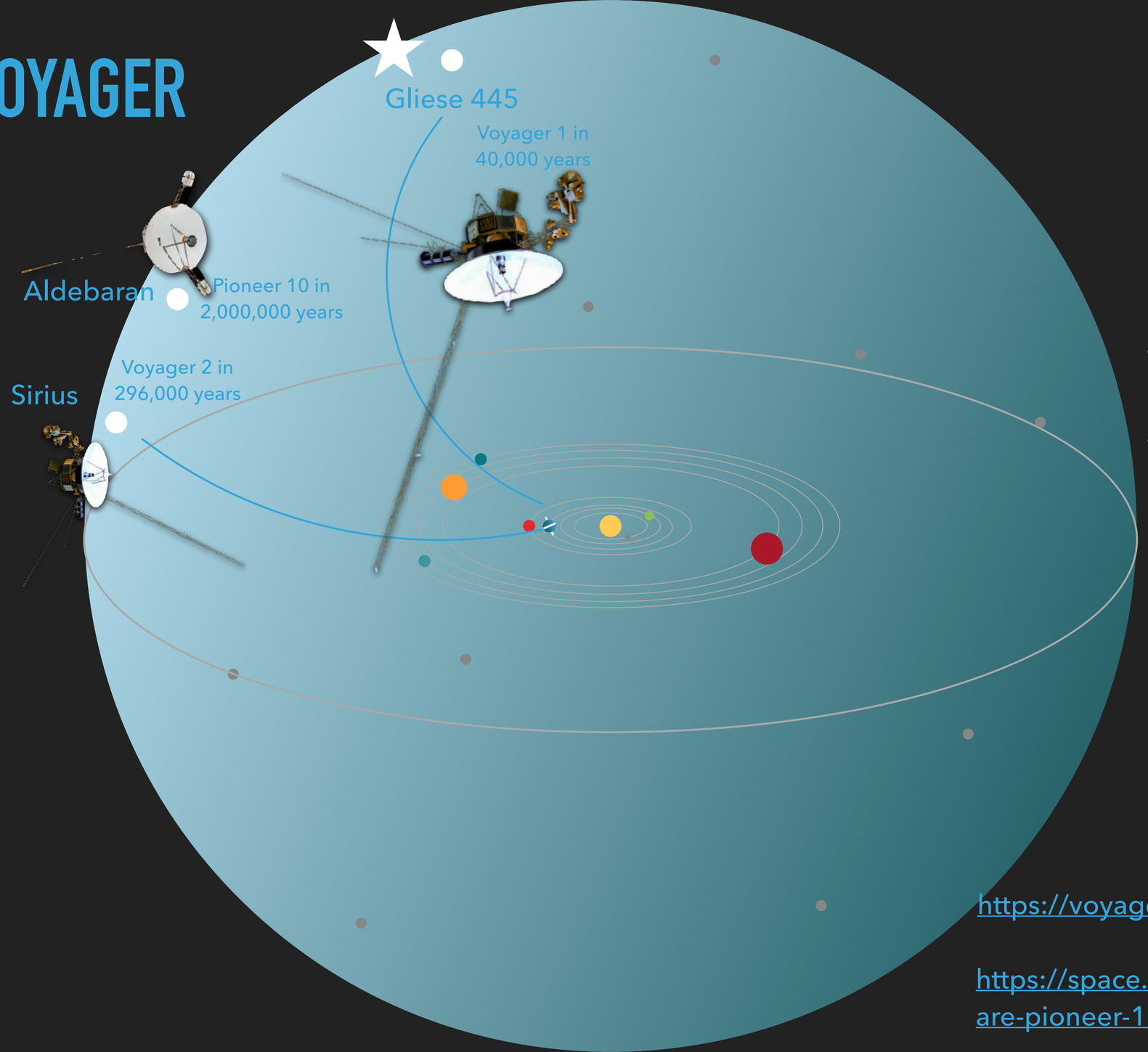
(The Arecebo Radio Telescope was decommissioned in 2020)





TIME IN PIONEER AND VOYAGER

VOYAGER



Current distance:

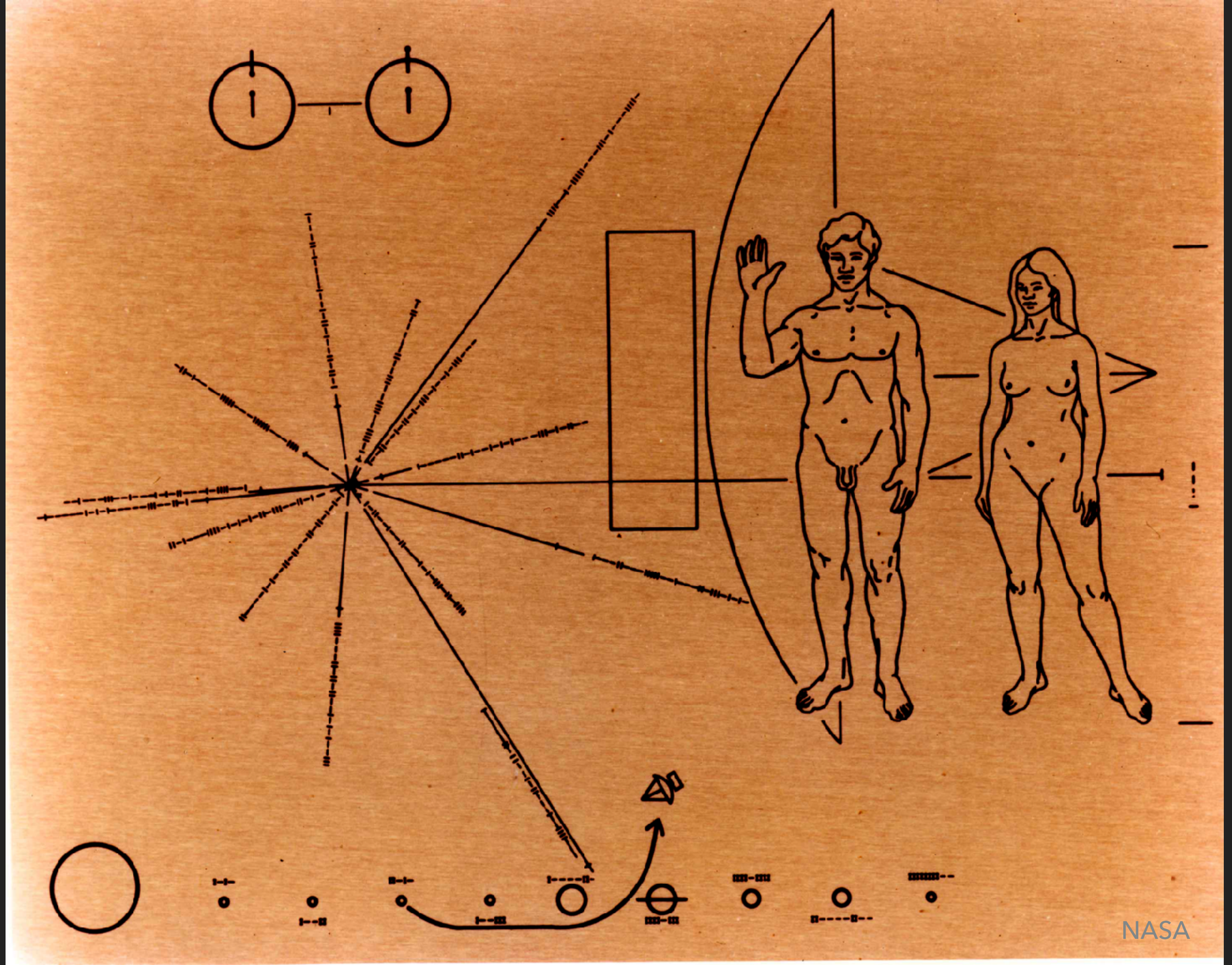
Voyager 1: 162.5 AU (22.5 lh)

Voyager 2: 135.5 AU (18.75 lh)

https://voyager.jpl.nasa.gov/mission/status/

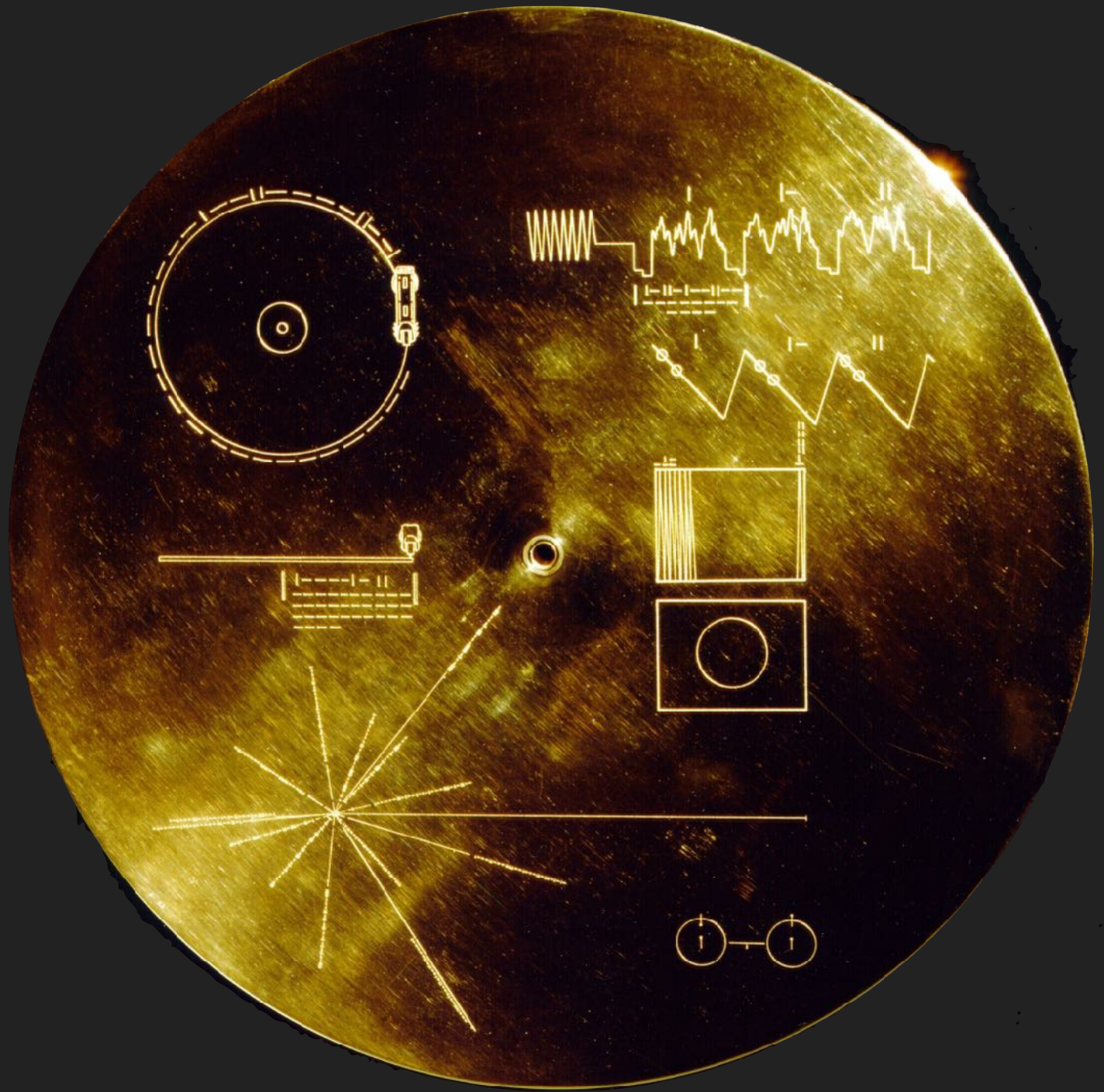
https://space.stackexchange.com/questions/1621/where-are-pioneer-10-11-and-the-voyagers-ultimately-headed

PIONEER

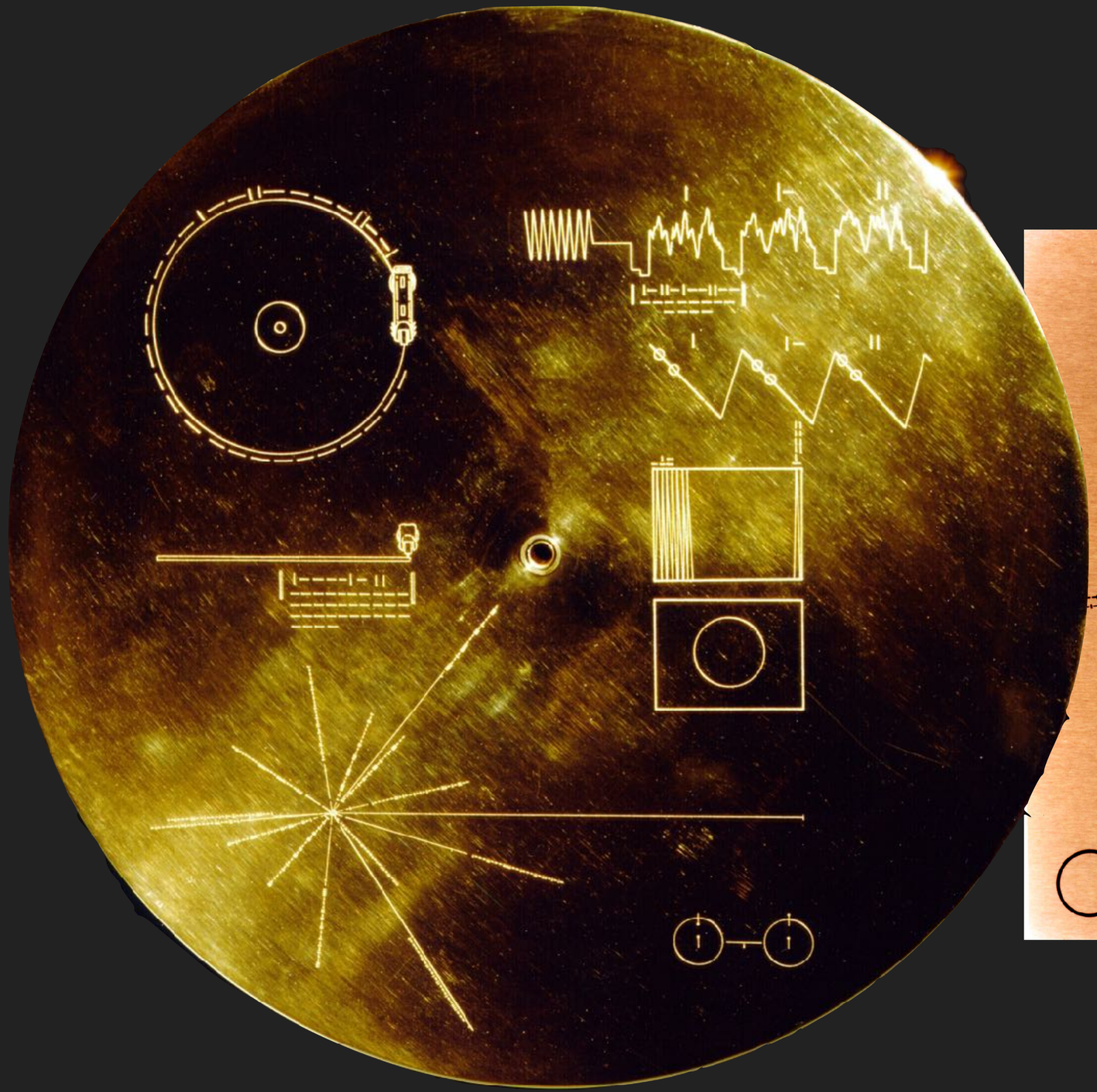


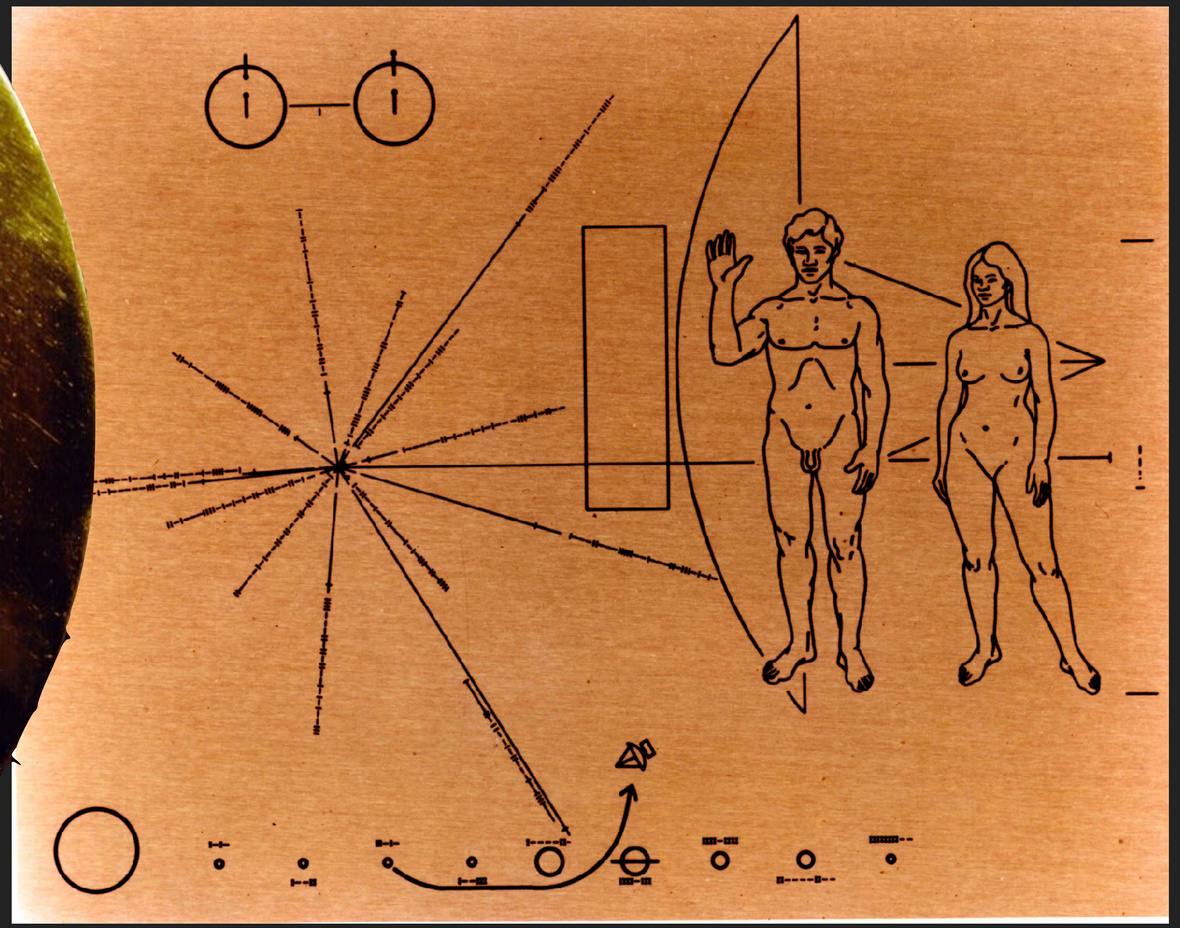
NASA

VOYAGER

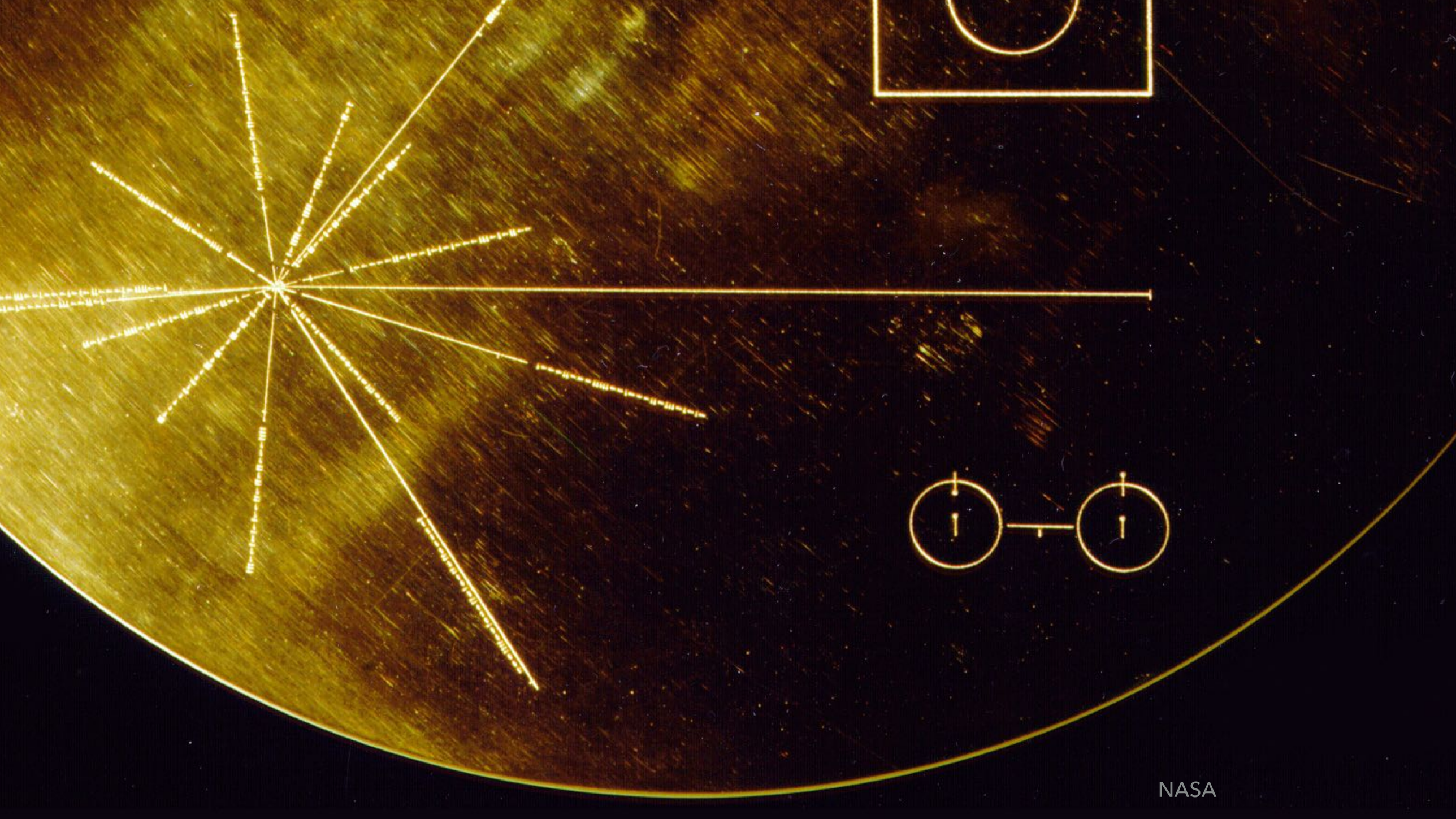


NASA

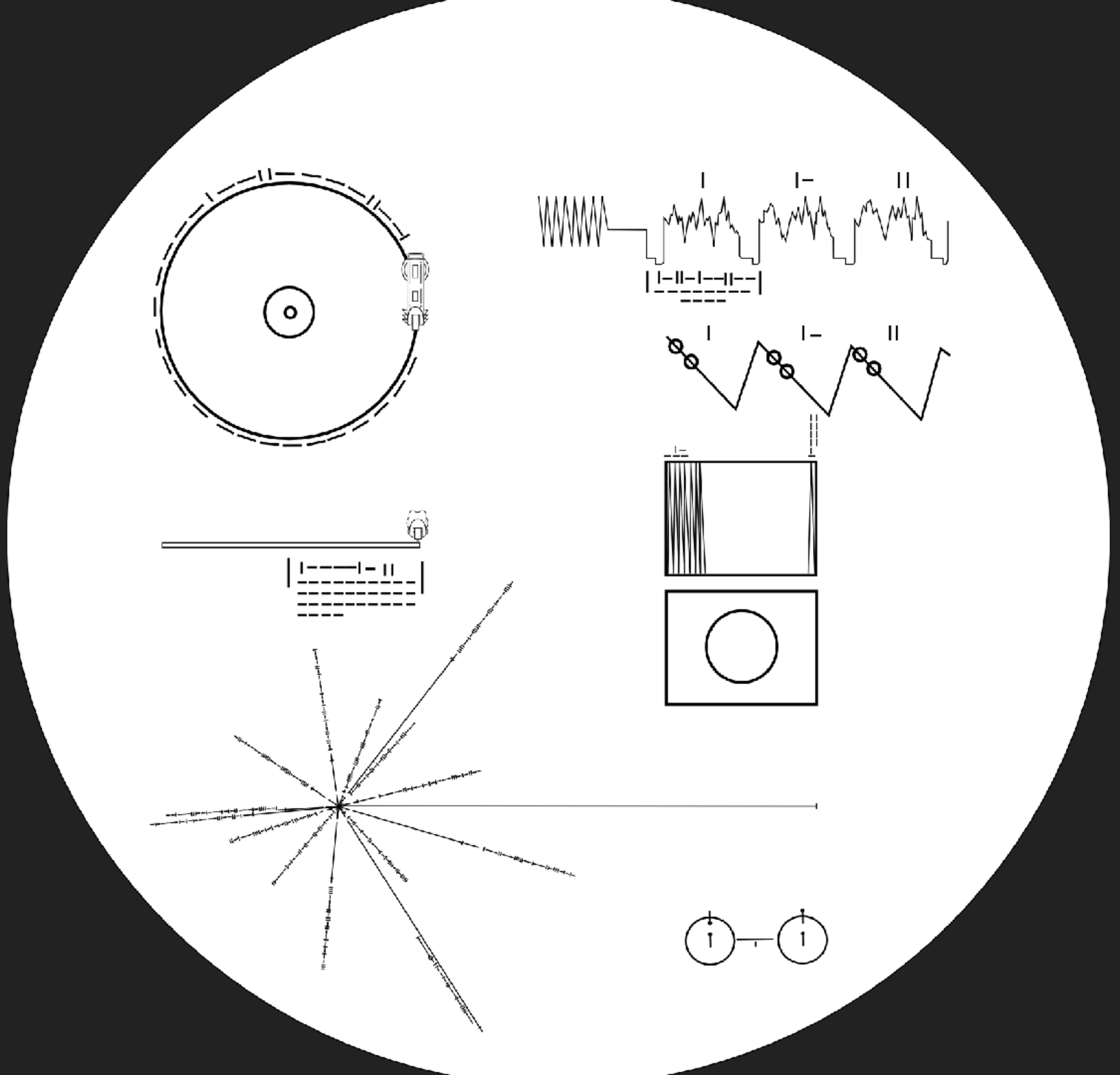




NASA



NASA



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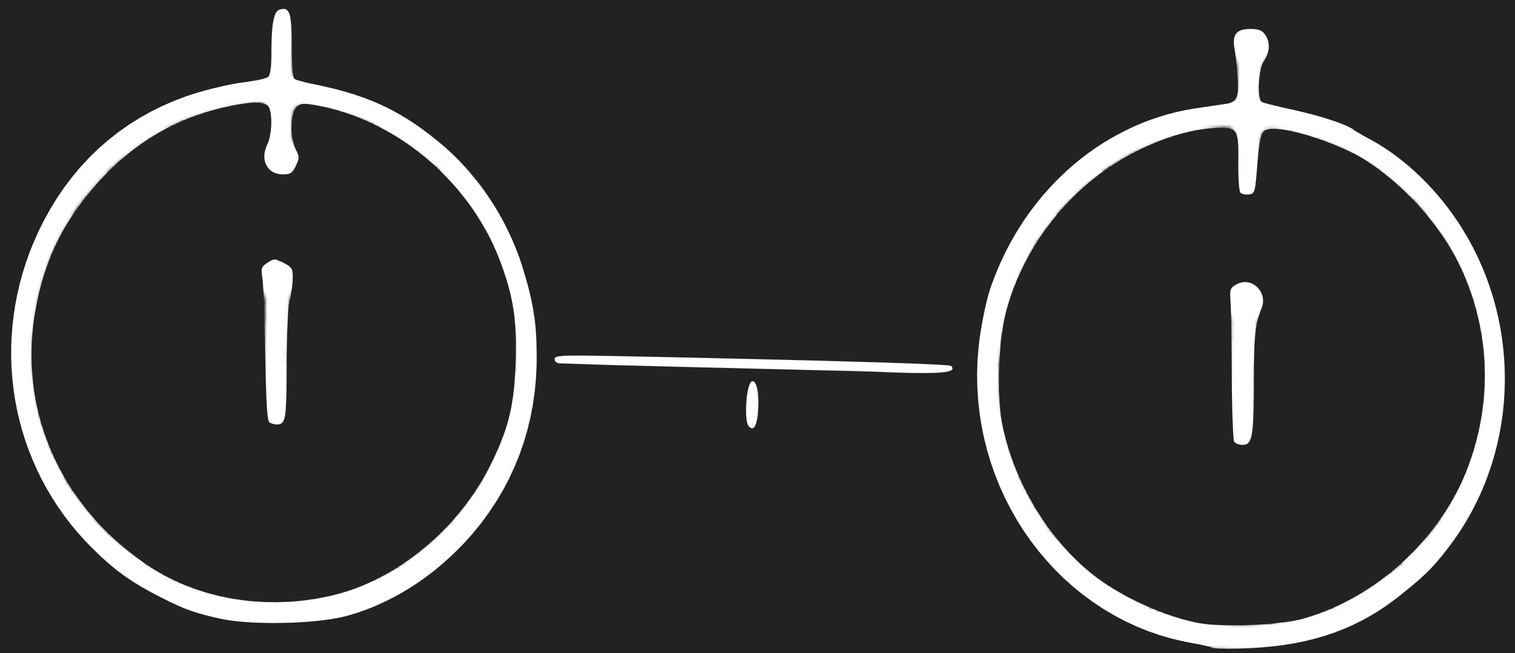
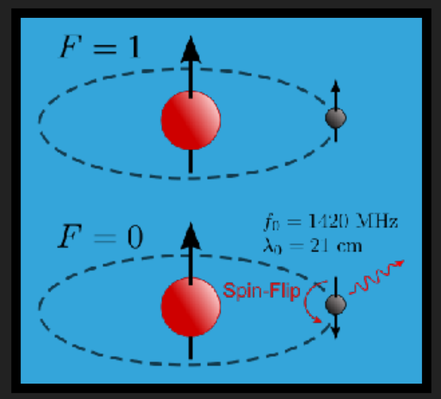
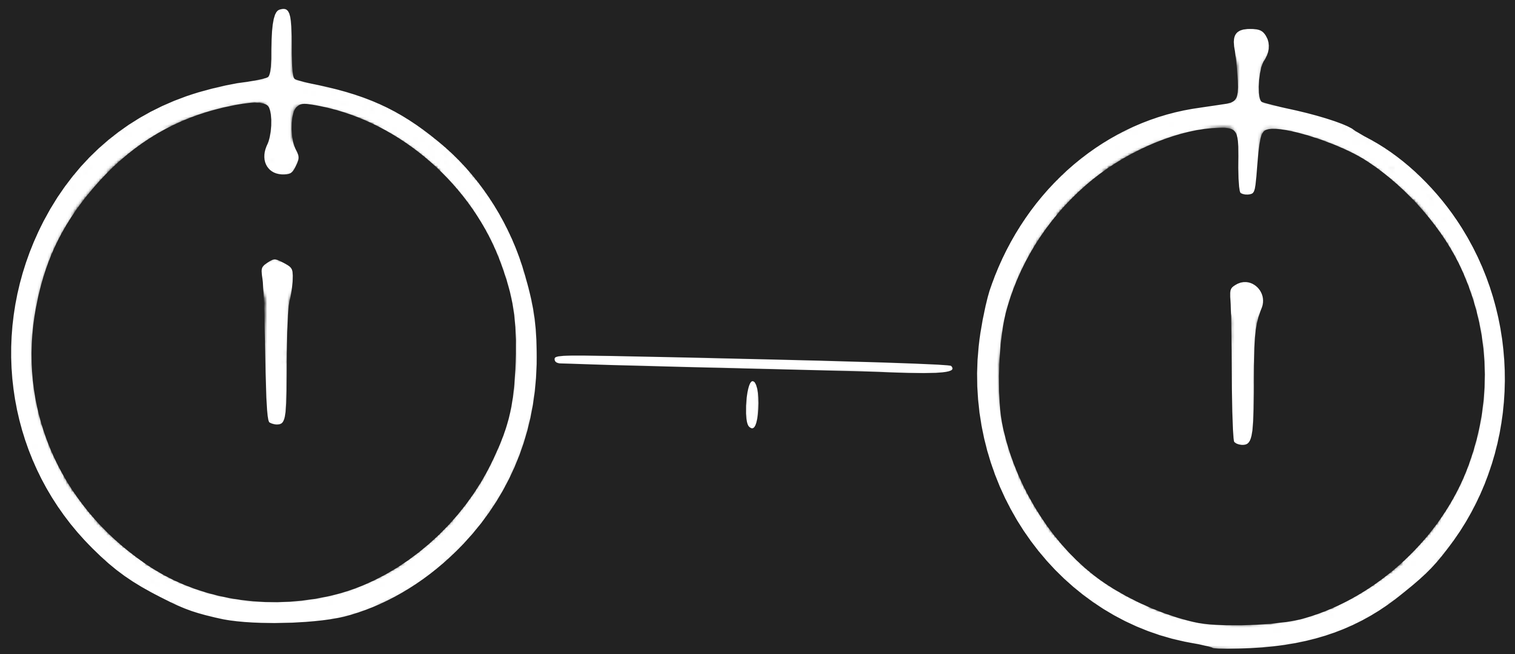
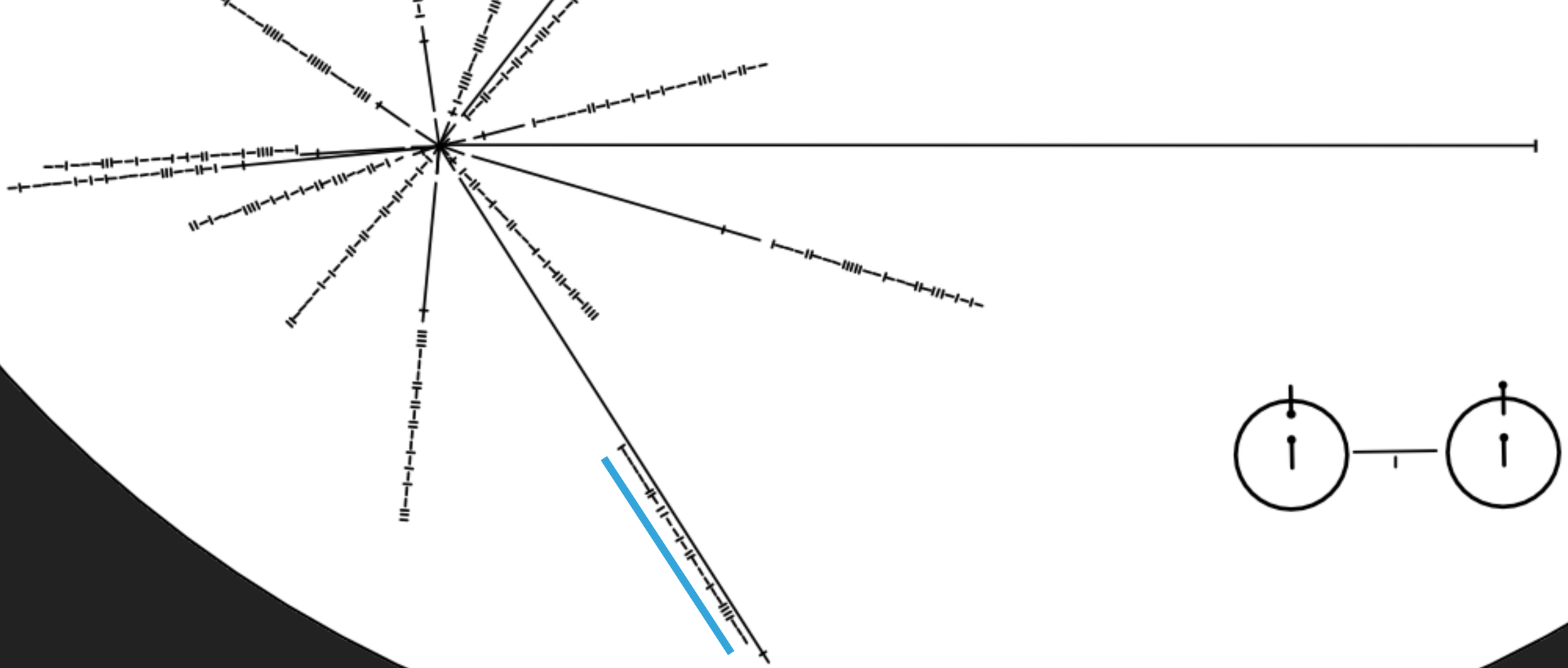


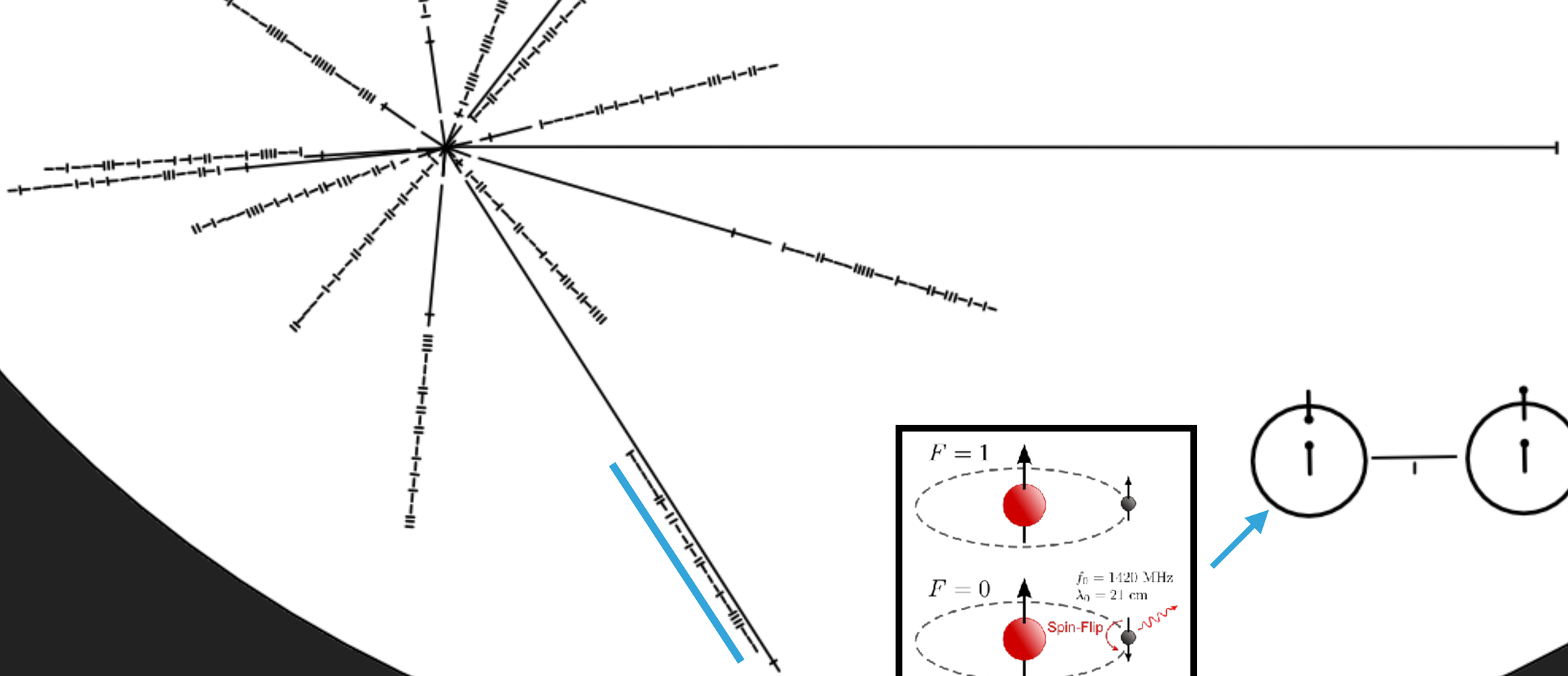




“During the 1930s, it was noticed that there was a radio 'hiss' that varied on a daily cycle and appeared to be extraterrestrial in origin. After initial suggestions that this was due to the Sun, it was observed that the radio waves seemed to propagate from the centre of the Galaxy”

Wikipedia

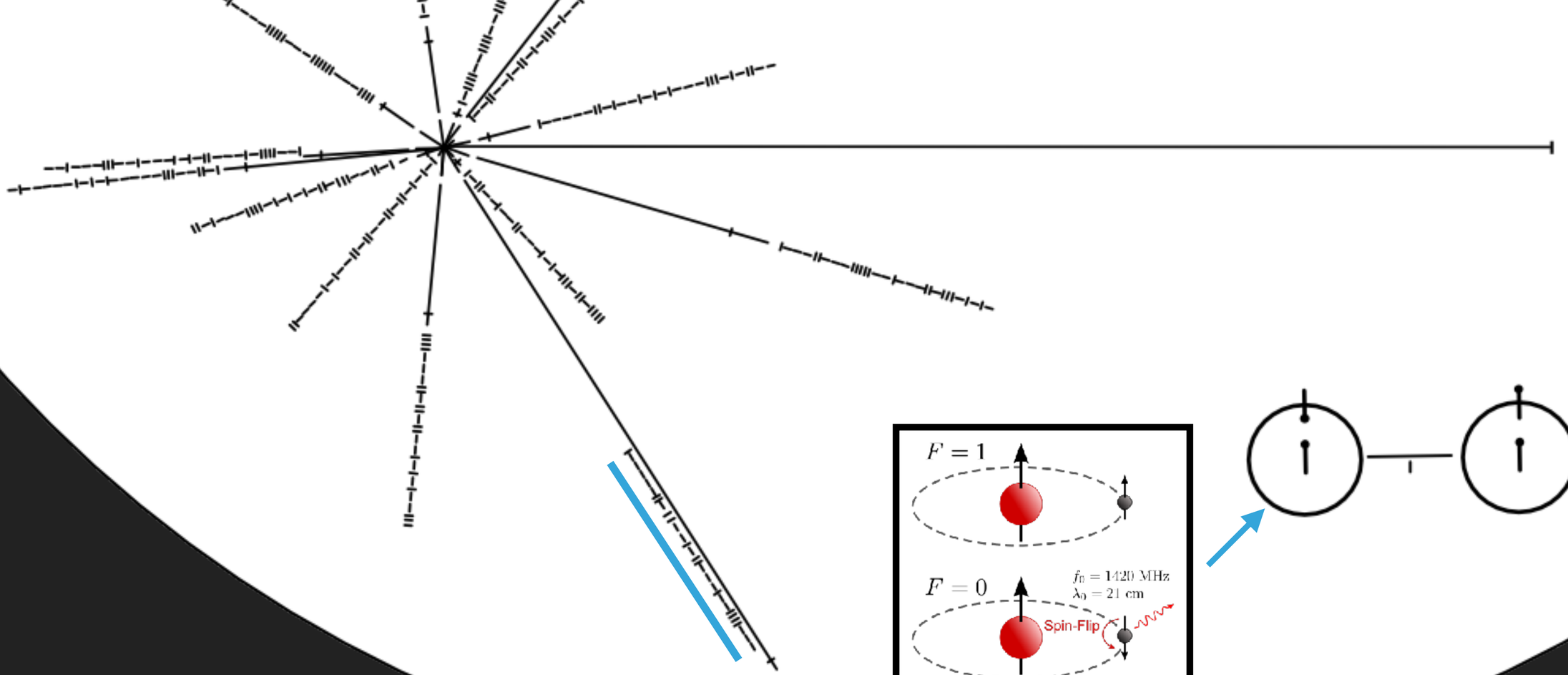




$f = 1420\text{Mhz}$

$d = 1/f$

NASA

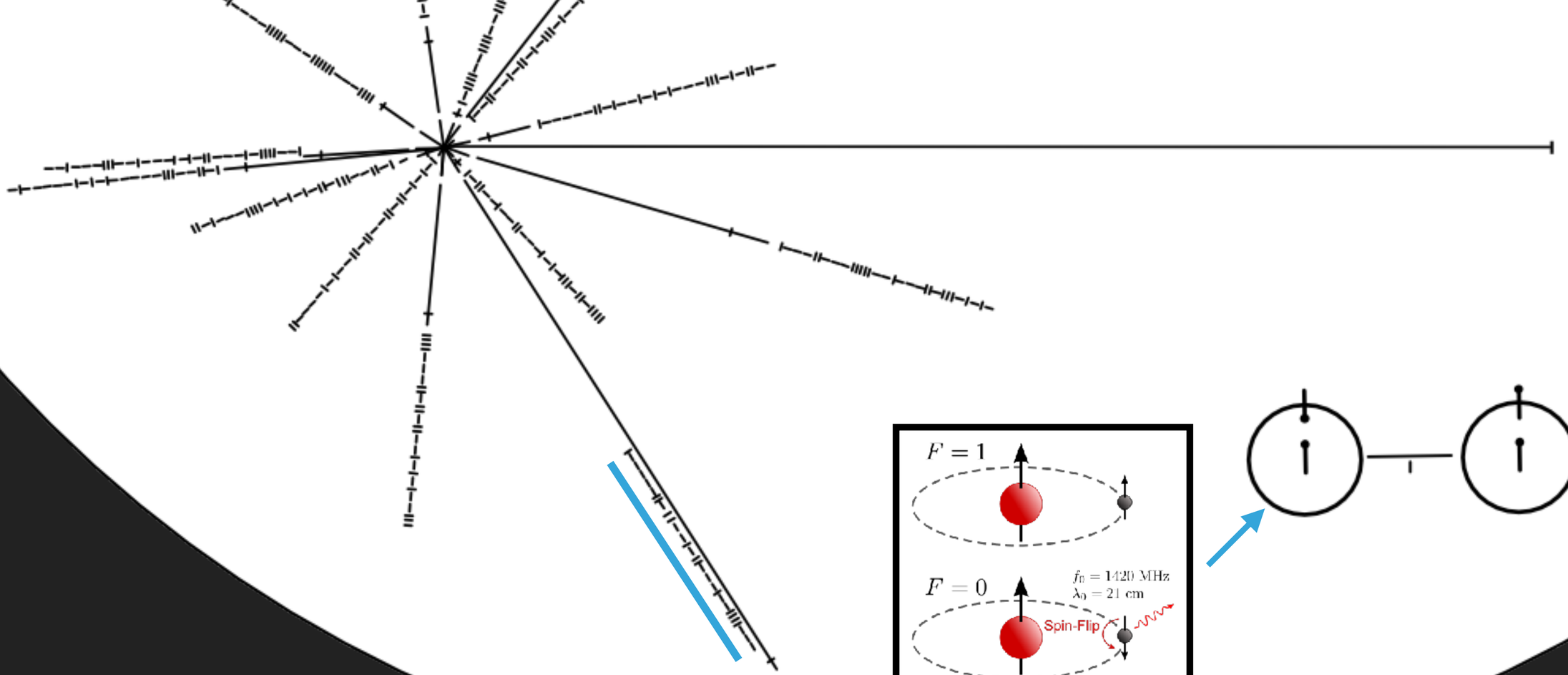


10000011011001011000100111100O

$f = 1420Mhz$

$d = 1/f$

NASA



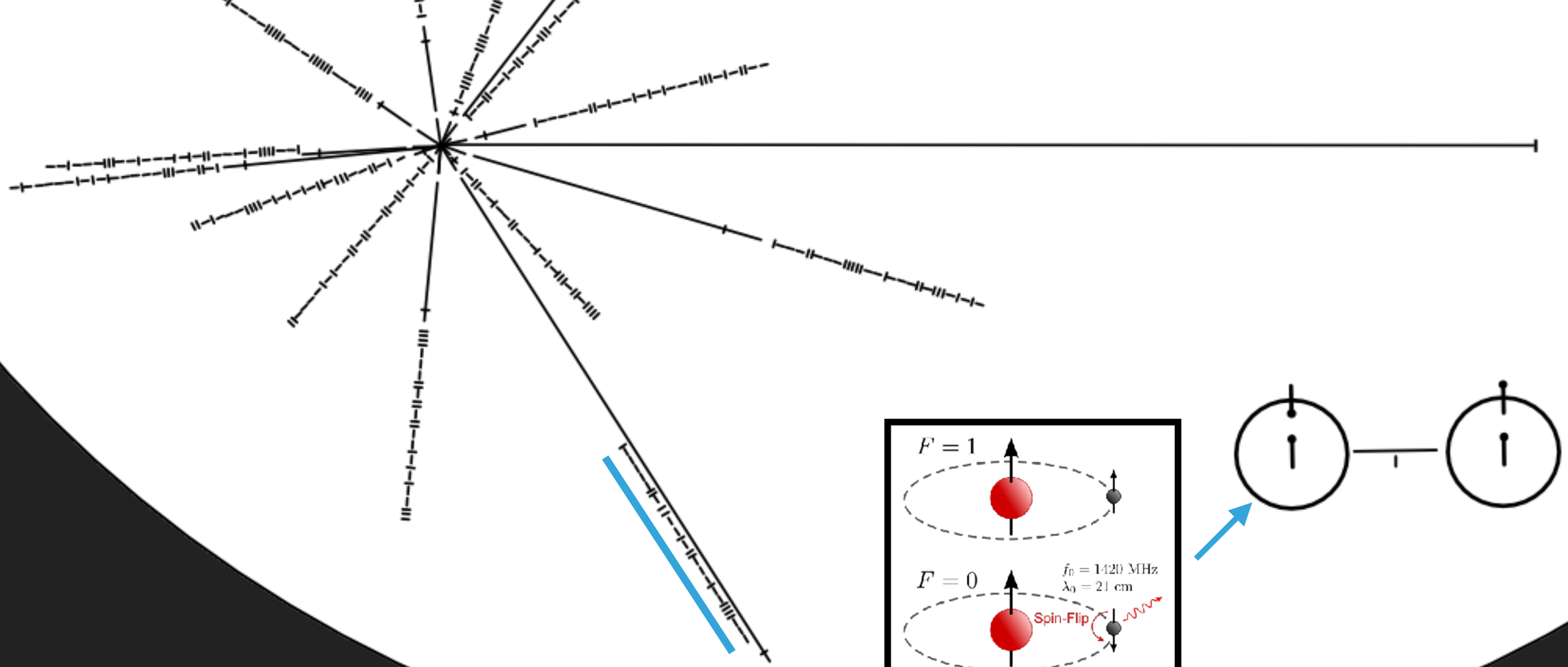
10000011011001011000100111100 0

= 551117432

f **= 1420Mhz**

d = 1/*f*

NASA

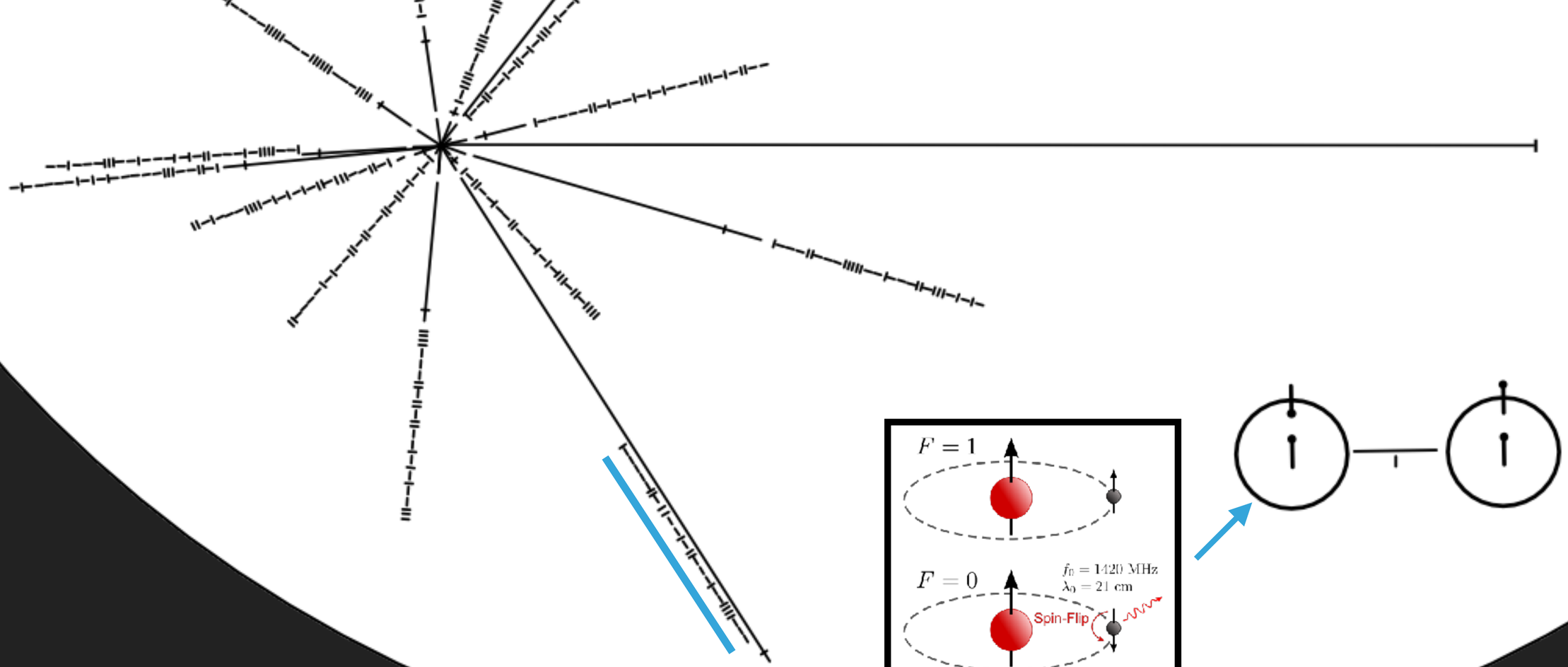


100000110110010110001001111000
= 551117432 * 1/*f* = .388s

f **= 1420Mhz**

d = 1/*f*

NASA



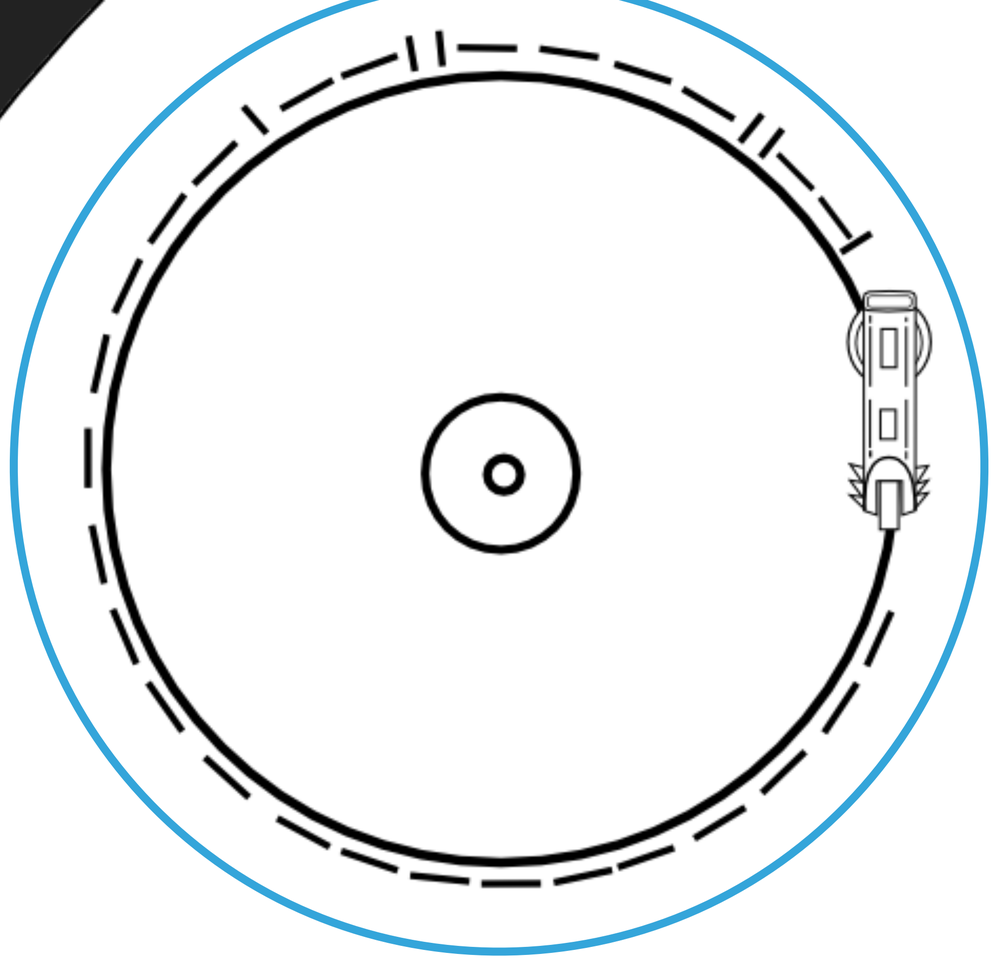
.388s = frequency of pulsar "1240" (aka J1243-6423)

-wikipedia

f = 1420Mhz

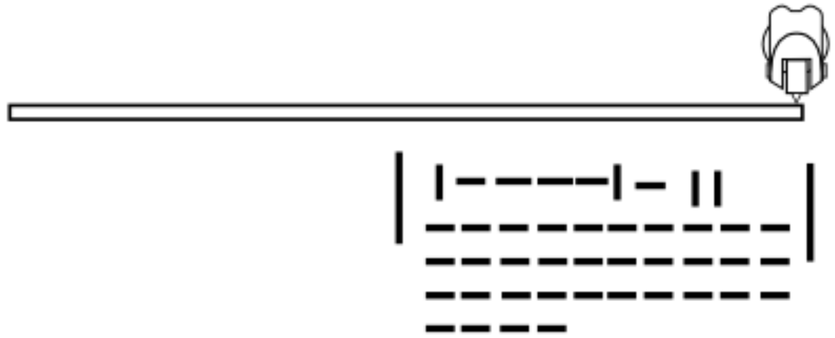
d = 1/***f***

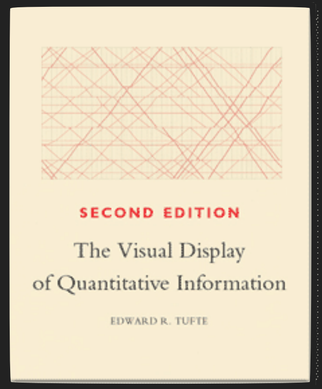
NASA

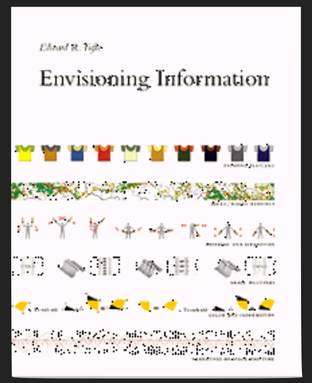


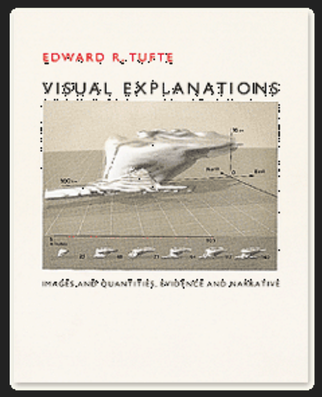
1001100001100100000000000000000000
= 5113380864 * 1/14204057517667
= 3.6 seconds / revolution
= ~16RPM

100001011 0000000000 0000000000 0000000000 0000
= 4587025072128 * 1/14204057517667
= 3229.3 seconds
= ~54 minutes

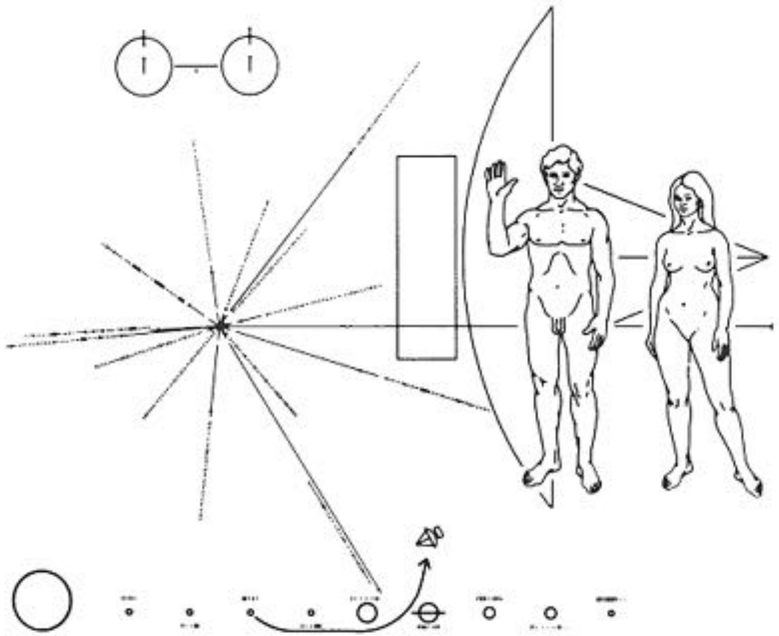








PIONEER SPACE PLAQUE REDESIGN



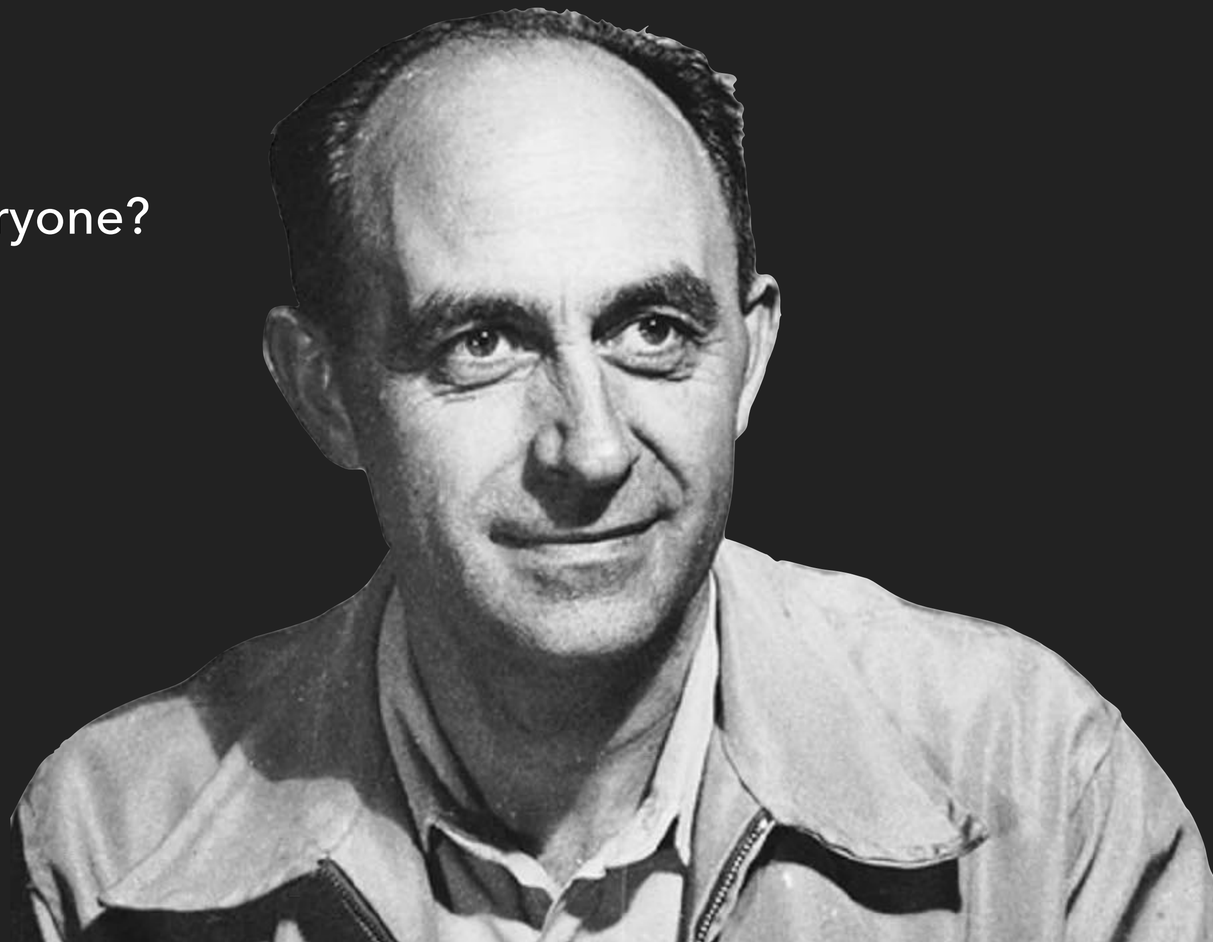
Magic, the production of entertaining illusions, has an appeal quite independent of the local specifics of language or culture. In vanishing objects or levitating assistants, conjurers amaze, delight, and even shock their audiences by the apparent violation of the universal laws of nature and our daily experience of those laws. Since the principles of physics hold everywhere, magic is conceivably a cosmological entertainment, with the wonder induced by theatrical illusions appreciated by all, regardless of planetary system. Accordingly the plaque aboard the Pioneer spacecraft for extraterrestrial scrutiny billions of years from now might have escaped from its conspicuously anthropocentric gestures by showing instead the universally familiar Amazing Levitation Trick.

EDWARD TUFTE

https://www.edwardtufte.com

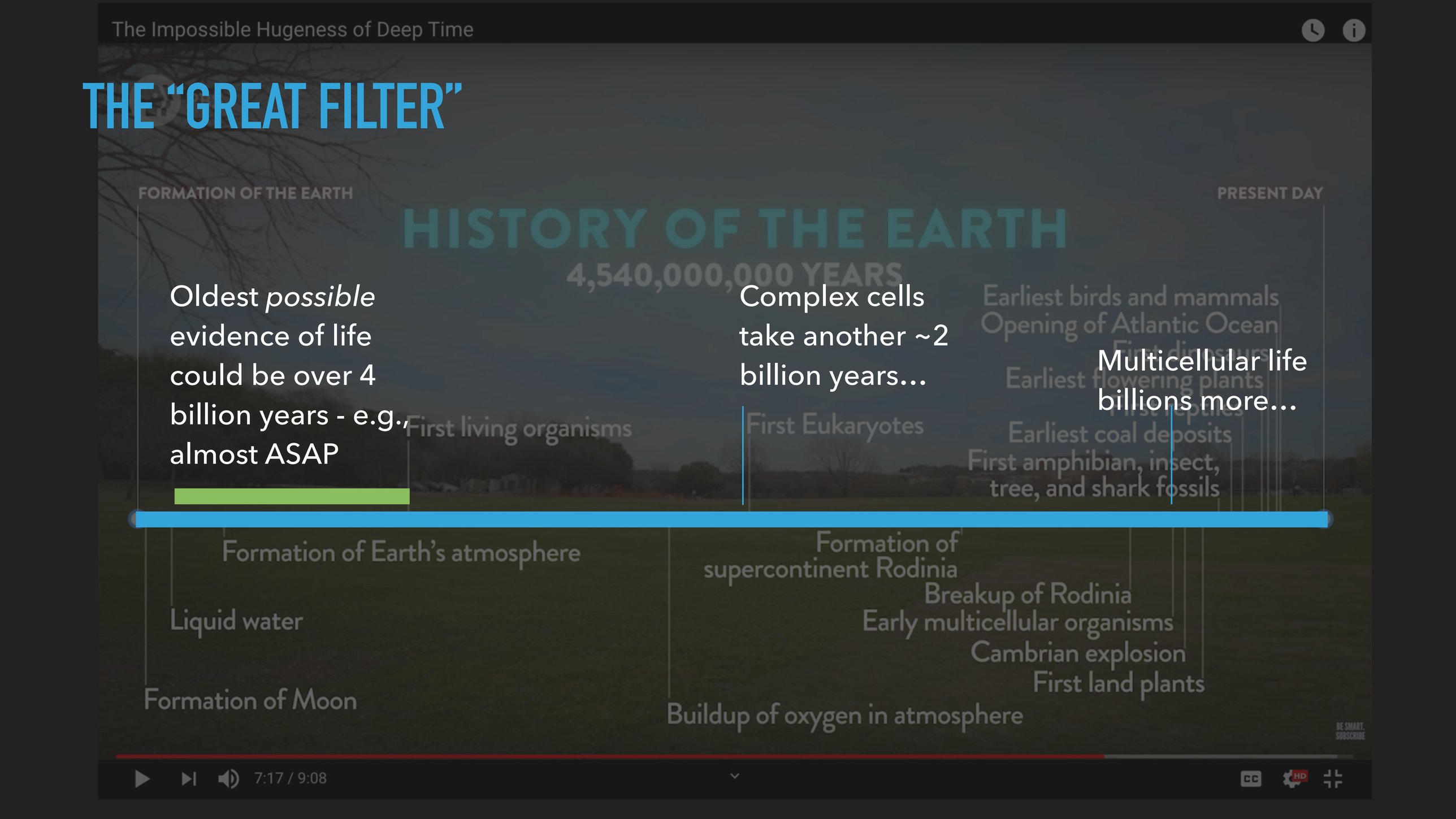
FERMI PARADOX

Where is everyone?



https://en.wikipedia.org/wiki/Fermi_paradox


The Impossible Hugeness of Deep Time
PBS
FORMATION OF THE EARTH
PRESENT DAY
HISTORY OF THE EARTH
4,540,000,000 YEARS
Earliest birds and mammals
Opening of Atlantic Ocean
First dinosaurs
Earliest flowering plants
First reptiles
Earliest coal deposits
First amphibian, insect, tree, and shark fossils
First living organisms
First Eukaryotes
Formation of Earth's atmosphere
Liquid water
Formation of Moon
Formation of supercontinent Rodinia
Breakup of Rodinia
Early multicellular organisms
Cambrian explosion
First land plants
Buildup of oxygen in atmosphere
BE SMART. SUBSCRIBE
7:17 / 9:08
CC
HD


The Impossible Hugeness of Deep Time
THE "GREAT FILTER"
FORMATION OF THE EARTH
PRESENT DAY
HISTORY OF THE EARTH
4,540,000,000 YEARS
Oldest *possible* evidence of life could be over 4 billion years - e.g., almost ASAP
Complex cells take another ~2 billion years...
Multicellular life billions more...
First living organisms
First Eukaryotes
Earliest birds and mammals
Opening of Atlantic Ocean
Earliest flowering plants
Earliest coal deposits
First amphibian, insect, tree, and shark fossils
Formation of Earth's atmosphere
Liquid water
Formation of Moon
Formation of supercontinent Rodinia
Breakup of Rodinia
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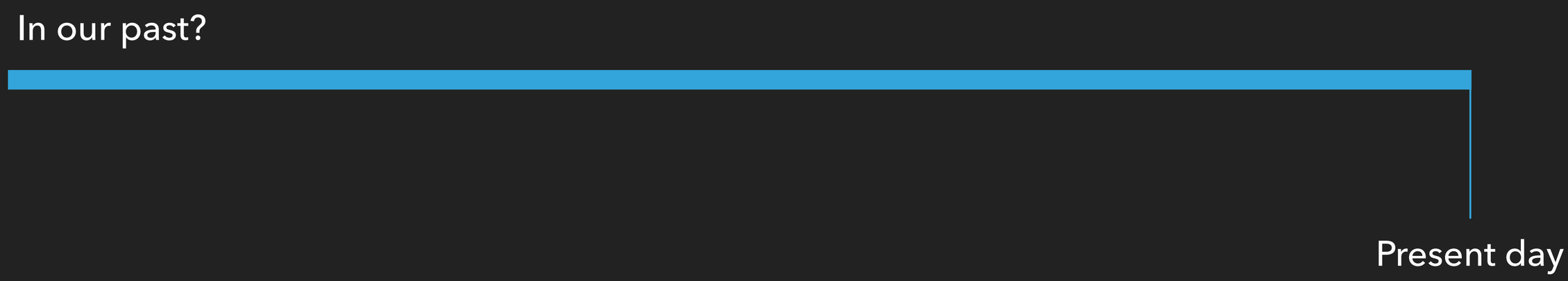
First land plants
Buildup of oxygen in atmosphere
BE SMART. SUBSCRIBE
7:17 / 9:08

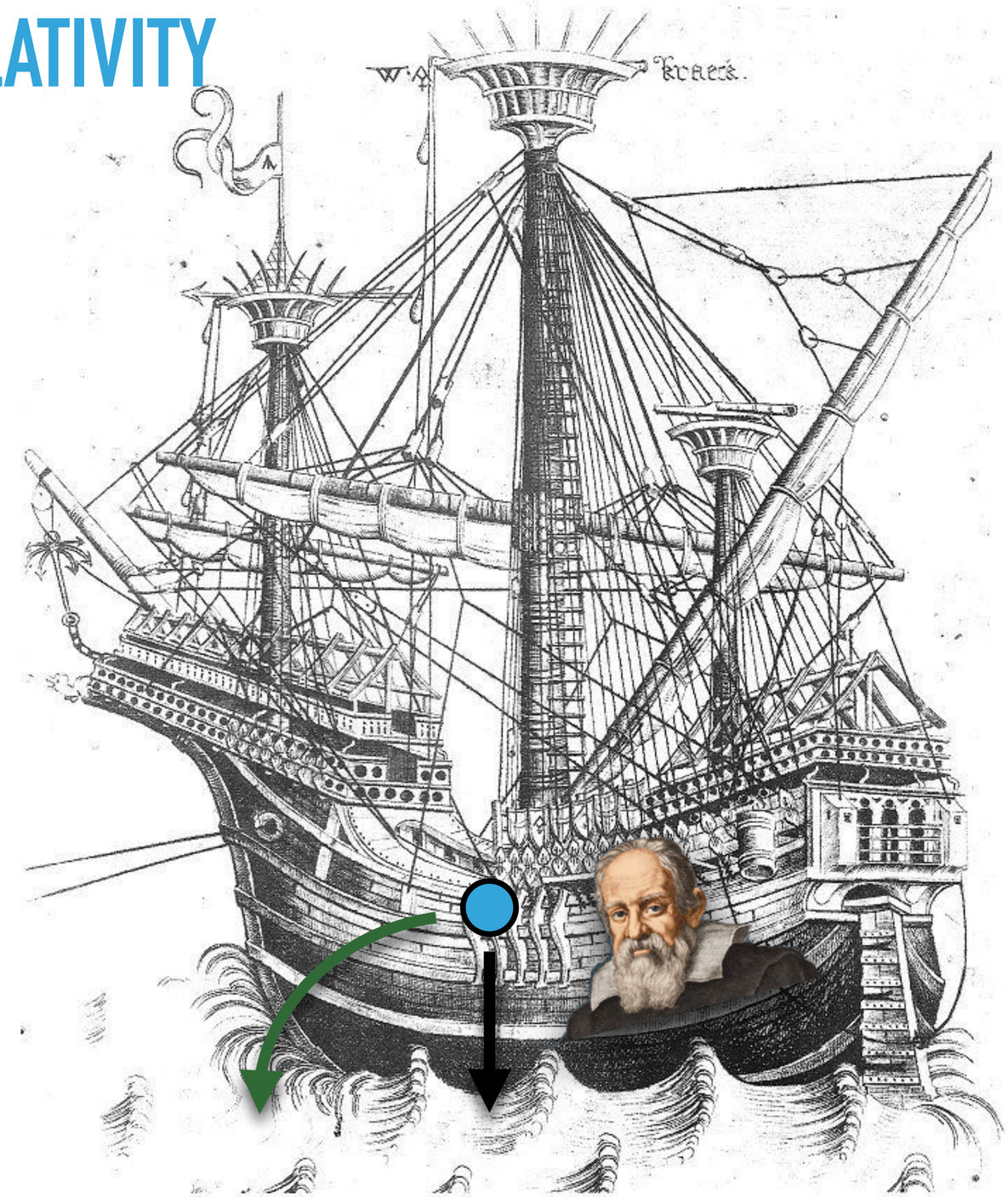
THE “GREAT FILTER”



THE “GREAT FILTER”

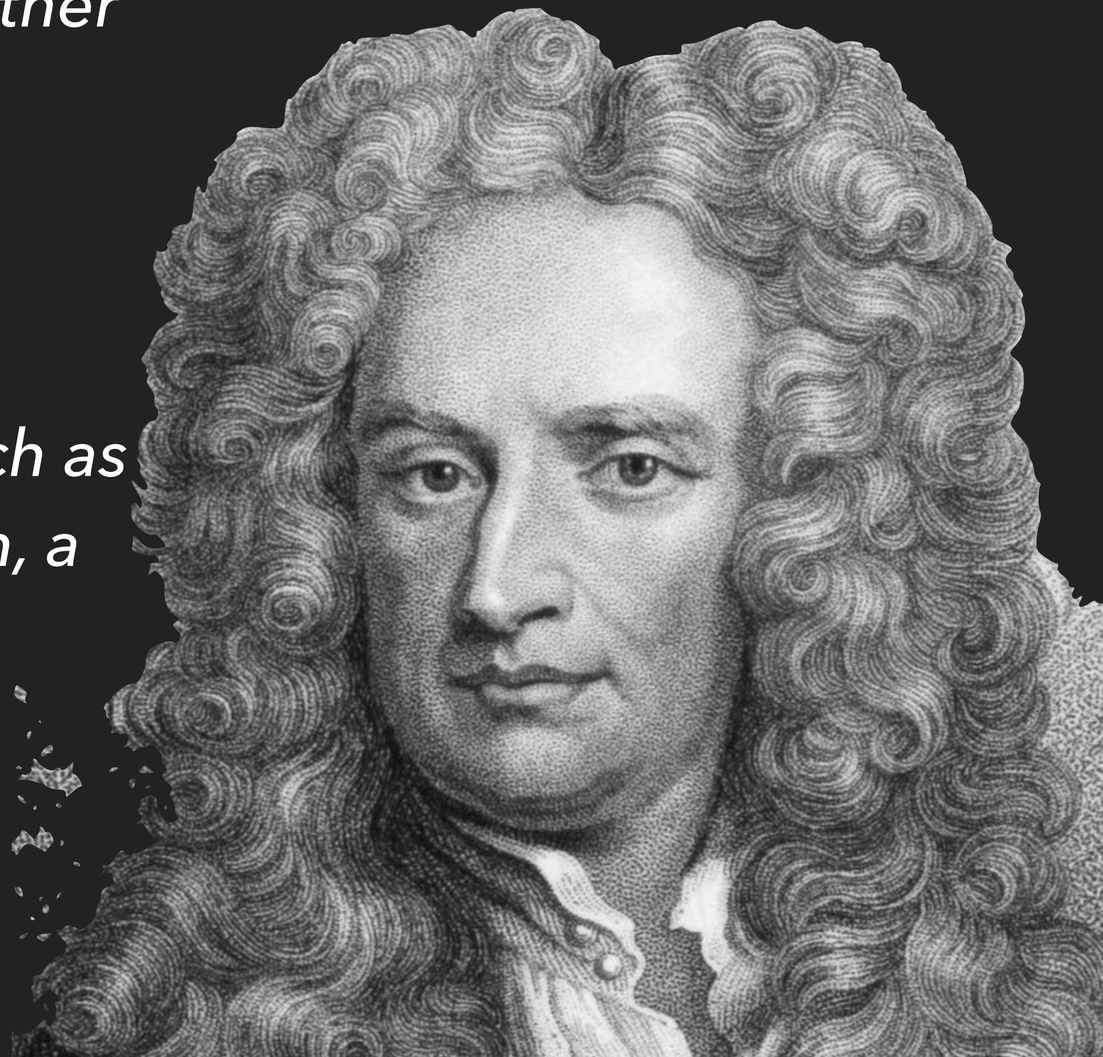
RELATIVITY

GALILEAN RELATIVITY



*"**Absolute, true, and mathematical time**, in and of itself and of its own nature, without reference to anything external, **flows uniformly** and by another name is called duration.*

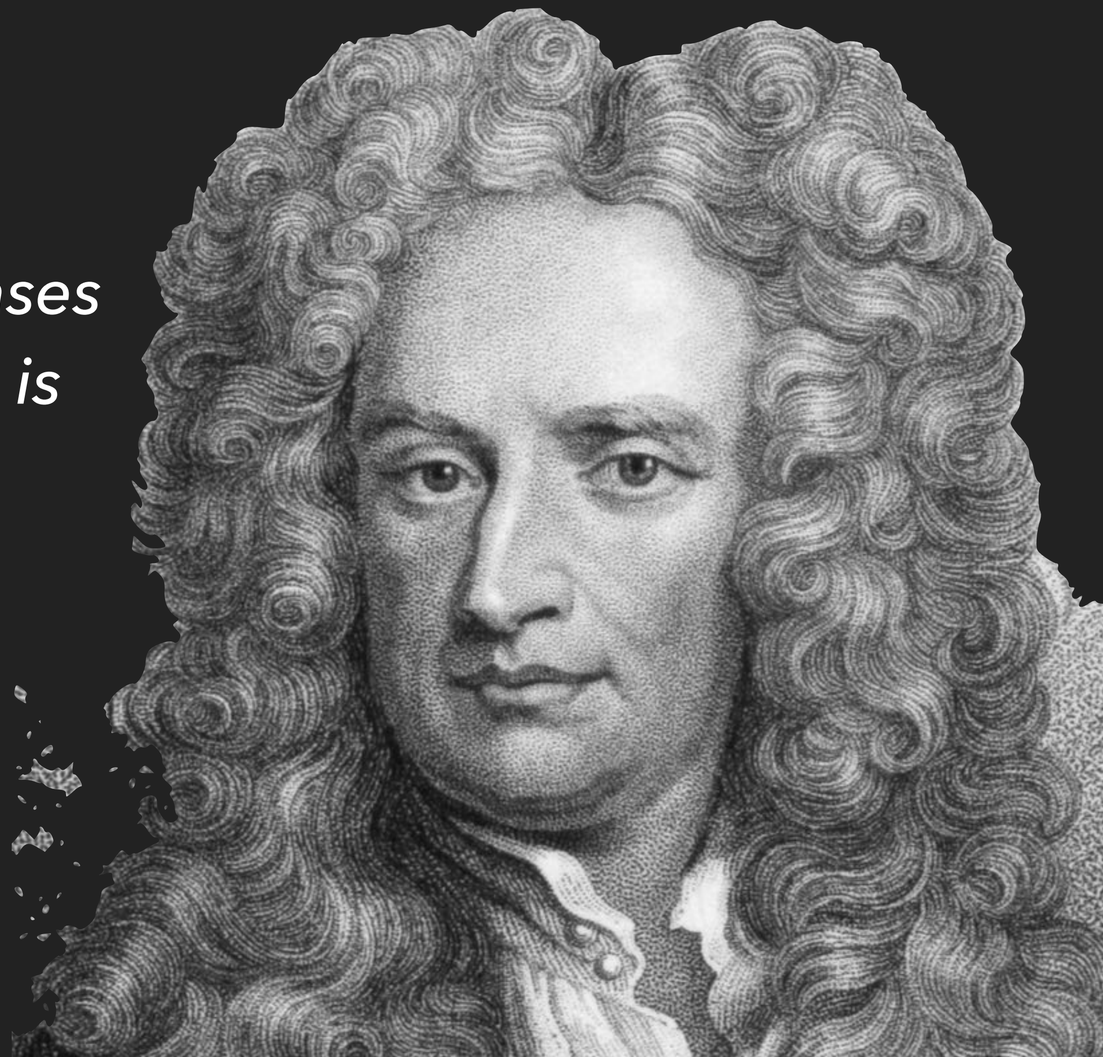
Relative, apparent, and common time is any sensible and external measure (precise or imprecise) of duration by means of motion; such as a measure-for example, an hour, a day, a month, a year-is commonly used instead of true time."



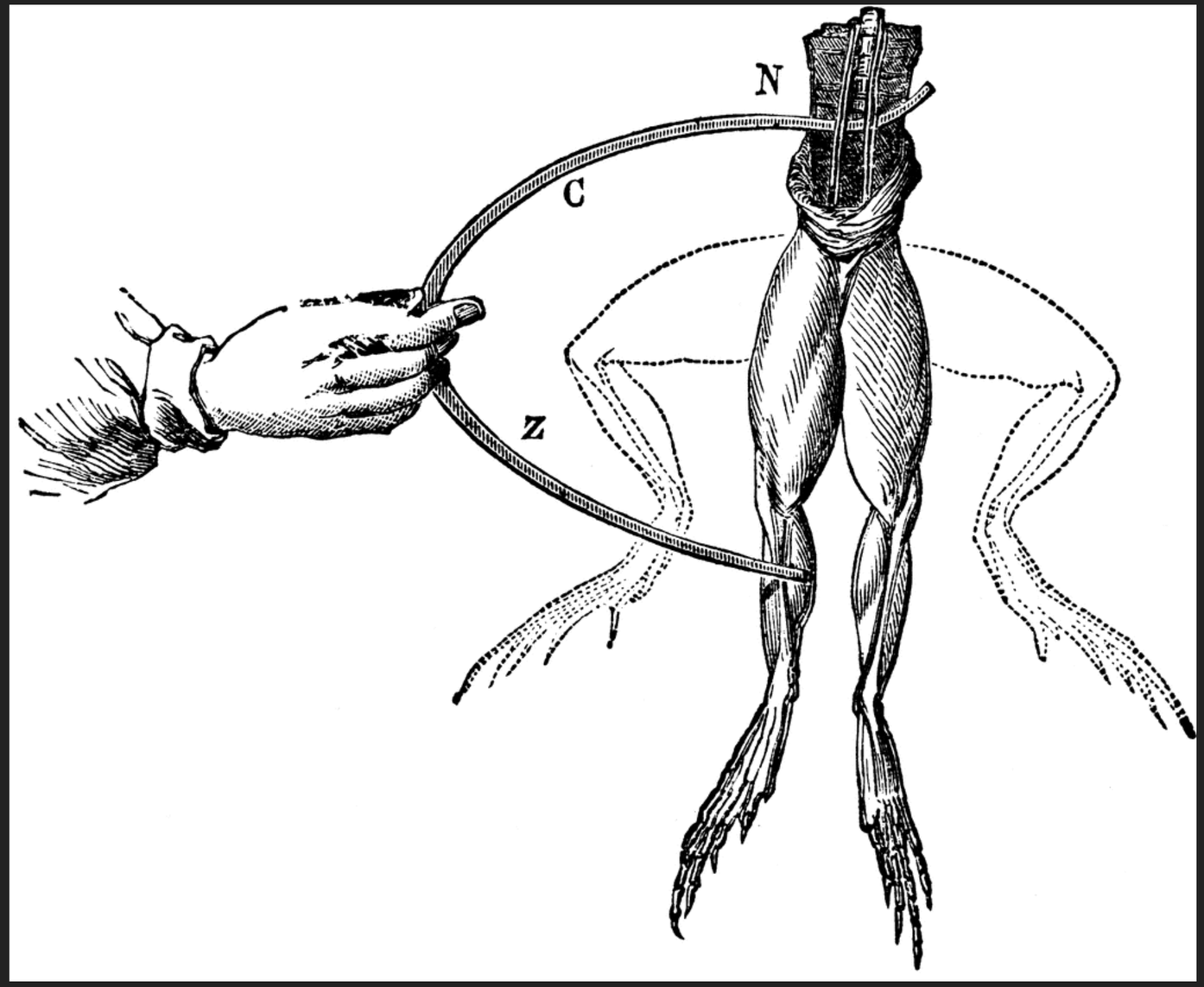
Newton's *Principia*, 1687

*“**Absolute space, in its own nature, without regard to anything external, remains always similar and immovable.***

Relative space is some movable dimension or measure of the absolute spaces, which our senses determine by its position to bodies, and which is vulgarly taken for immovable space.”

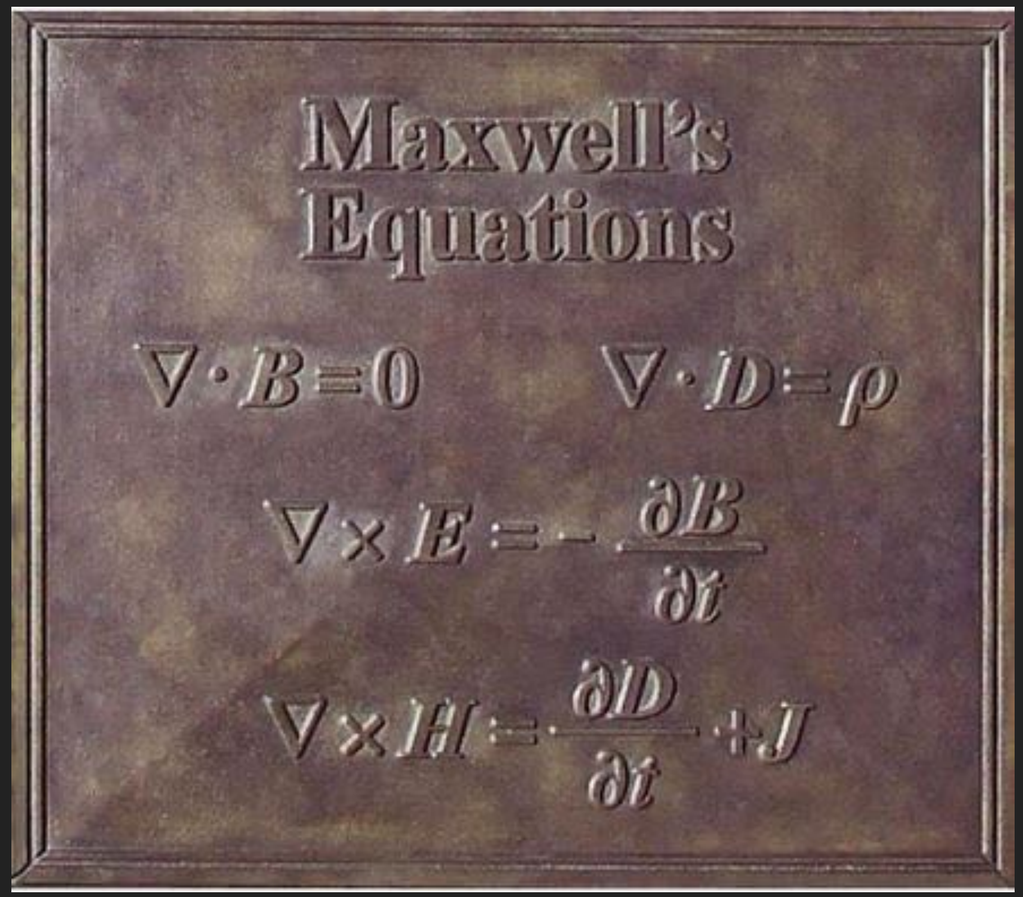


Newton’s *Principia*, 1687

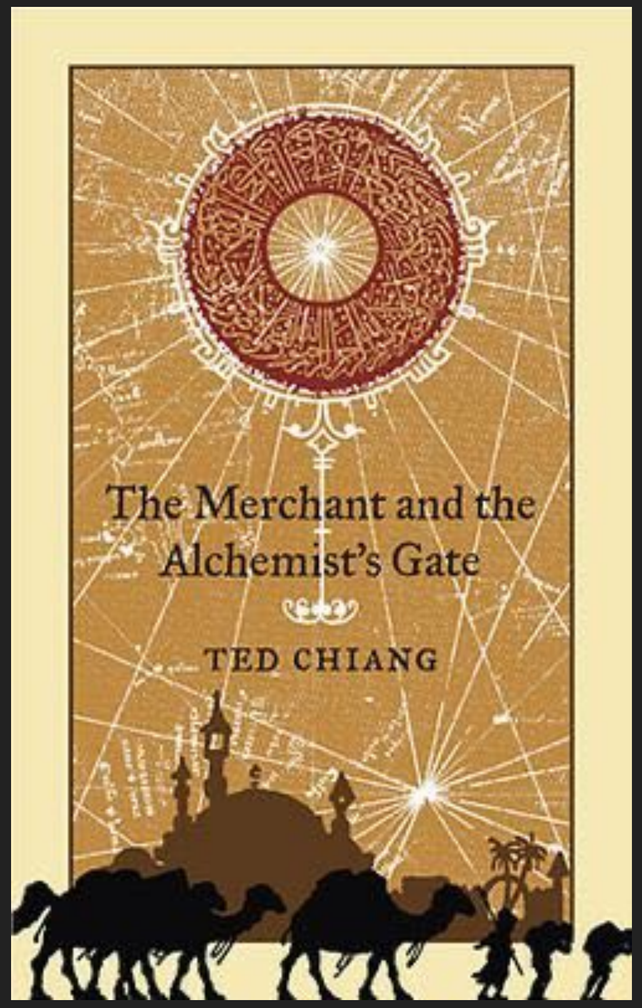


Electromagnetism is fundamental but also weird and subtle, and it took people a long time to figure it out

Two random examples over 3000 years


Maxwell's Equations
$\nabla \cdot B = 0$
$\nabla \cdot D = \rho$
$\nabla \times E = -\frac{\partial B}{\partial t}$
$\nabla \times H = \frac{\partial D}{\partial t} + J$

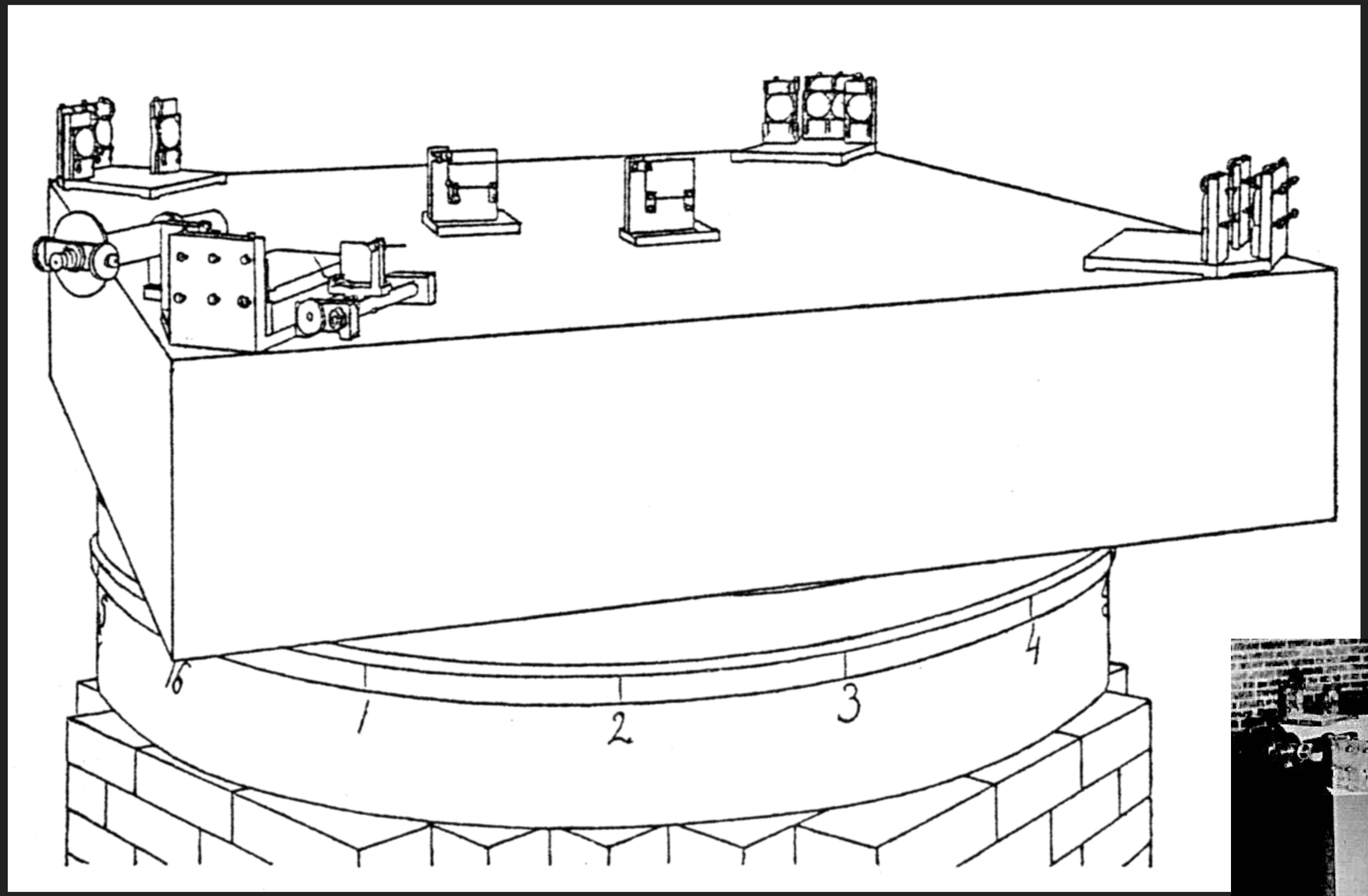
1861

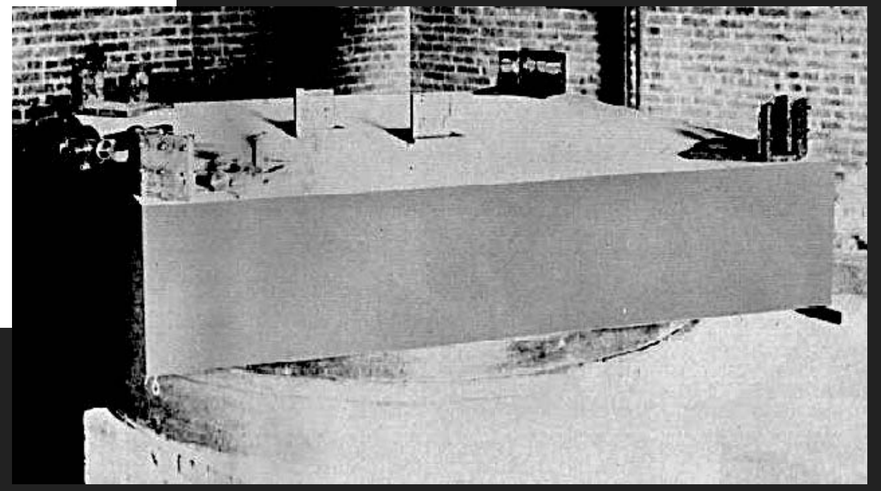


‘Bashaarat looked at me and considered. "I have recently built something that may change your opinion. You would be the first person I have shown it to. Would you care to see it?"

"It would be a great pleasure."

"Please follow me." He led me through the doorway in the rear of his shop. The next room was a workshop, arrayed with devices whose functions I could not guess—bars of metal wrapped with enough copper thread to reach the horizon, ***mirrors mounted on a circular slab of granite floating in quicksilver****—but Bashaarat walked past these without a glance.’*





Michelson–Morley experiment, 1887

"He handed the manuscript to me, and I saw the title was 'On the Relative Motion of the Sun and the Luminiferous Aether.' I have only a layperson's understanding of the aether, the medium that carries light waves: I know that, just as a shout carries farther when traveling with the wind than against it, ***the speed of light varies relative to the Earth's own motion through the aether****… there appears to be a steady aetheric wind across the solar system as a whole…"*

From 'Omphalos' by Ted Chiang.
Image: The Omphalos ('religious stone') of Delphi, wikipedia.

ON THE ELECTRODYNAMICS OF MOVING BODIES

EINSTEIN, 1905

3. *Zur Elektrodynamik bewegter Körper;*
von A. Einstein.

Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhaften scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Magneten und einem Leiter. Das beobachtbare Phänomen hängt hier nur ab von der Relativbewegung von Leiter und Magnet, während nach der üblichen Auffassung die beiden Fälle, daß der eine oder der andere dieser Körper der bewegte sei, streng voneinander zu trennen sind. Bewegt sich nämlich der Magnet und ruht der Leiter, so entsteht in der Umgebung des Magneten ein elektrisches Feld von gewissem Energiewerte, welches an den Orten, wo sich Teile des Leiters befinden, einen Strom erzeugt. Ruht aber der Magnet und bewegt sich der Leiter, so entsteht in der Umgebung des Magneten kein elektrisches Feld, dagegen im Leiter eine elektromotorische Kraft, welcher an sich keine Energie entspricht, die aber — Gleichheit der Relativbewegung bei den beiden ins Auge gefaßten Fällen vorausgesetzt — zu elektrischen Strömen von derselben Größe und demselben Verlaufe Veranlassung gibt, wie im ersten Falle die elektrischen Kräfte.

Beispiele ähnlicher Art, sowie die mißlungenen Versuche, eine Bewegung der Erde relativ zum „Lichtmedium“ zu konstatieren, führen zu der Vermutung, daß dem Begriffe der absoluten Ruhe nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen entsprechen, sondern daß vielmehr für alle Koordinatensysteme, für welche die mechanischen Gleichungen gelten, auch die gleichen elektrodynamischen und optischen Gesetze gelten, wie dies für die Größen erster Ordnung bereits erwiesen ist. Wir wollen diese Vermutung (deren Inhalt im folgenden „Prinzip der Relativität“ genannt werden wird) zur Voraussetzung erheben und außerdem die mit ihm nur scheinbar unverträgliche

ON THE ELECTRODYNAMICS OF MOVING BODIES

EINSTEIN, 1905

$$\xi = a\frac{c^2}{c^2 - v^2}x'.$$

In an analogous manner we find, by considering rays moving along the two other axes, that

$$\eta = c\tau = ac\left(t - \frac{v}{c^2 - v^2}x'\right)$$

when

$$\frac{y}{\sqrt{c^2 - v^2}} = t,\ x' = 0.$$

Thus

$$\eta = a\frac{c}{\sqrt{c^2 - v^2}}y \text{ and } \zeta = a\frac{c}{\sqrt{c^2 - v^2}}z.$$

Substituting for x' its value, we obtain

$$\begin{aligned}
\tau &= \phi(v)\beta(t - vx/c^2), \\
\xi &= \phi(v)\beta(x - vt), \\
\eta &= \phi(v)y, \\
\zeta &= \phi(v)z,
\end{aligned}$$

where

$$\beta = \frac{1}{\sqrt{1 - v^2/c^2}},$$

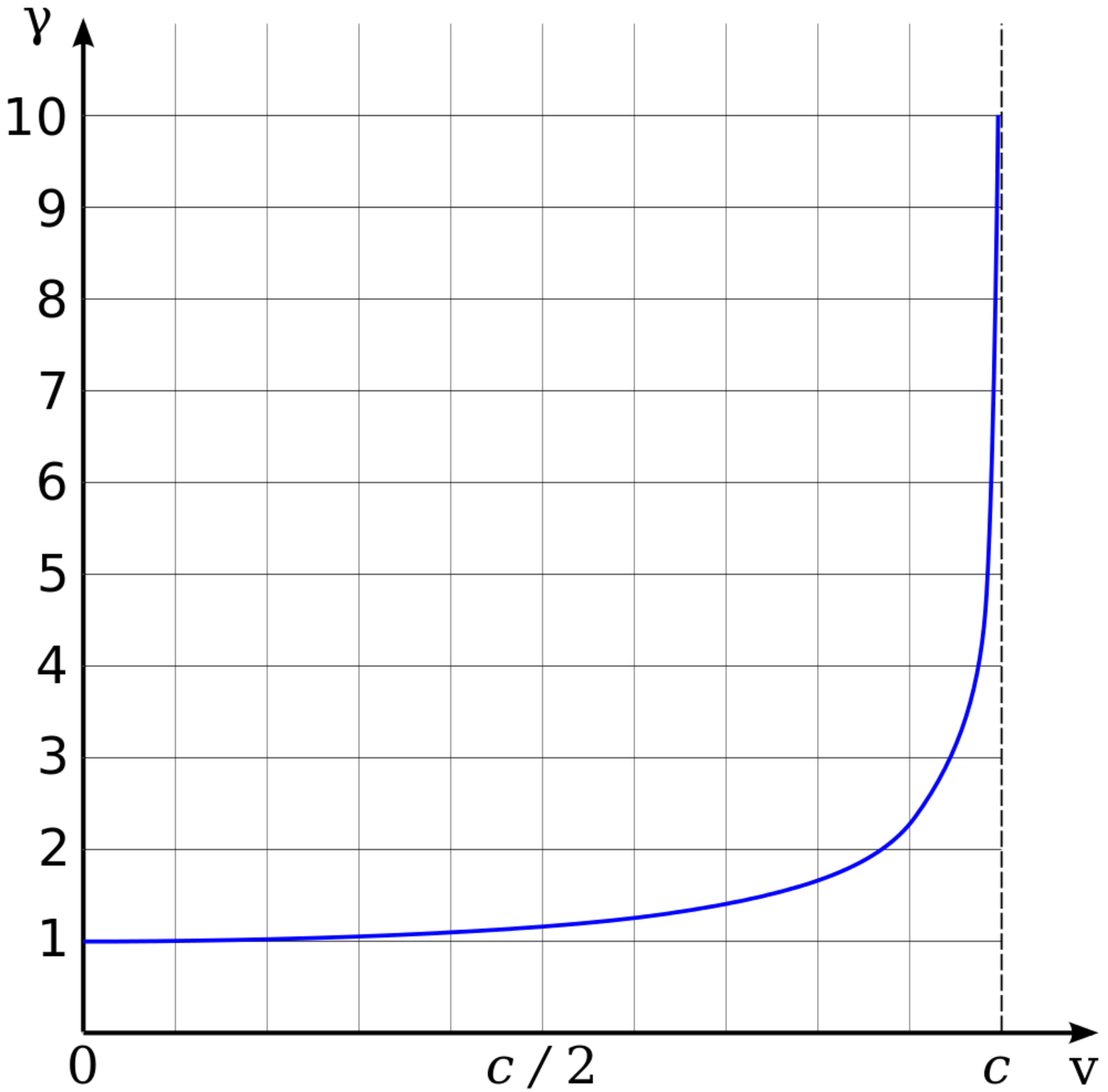
New t
New x
Same y
Same z

ON THE ELECTRODYNAMICS OF MOVING BODIES

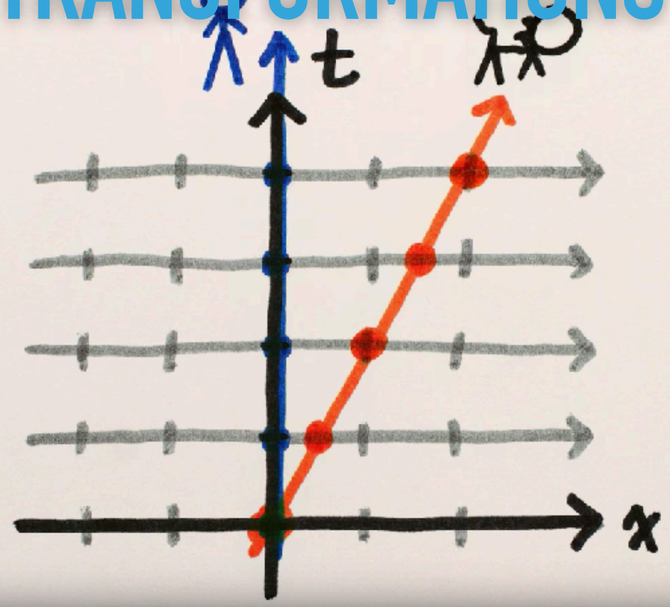
EINSTEIN, 1905

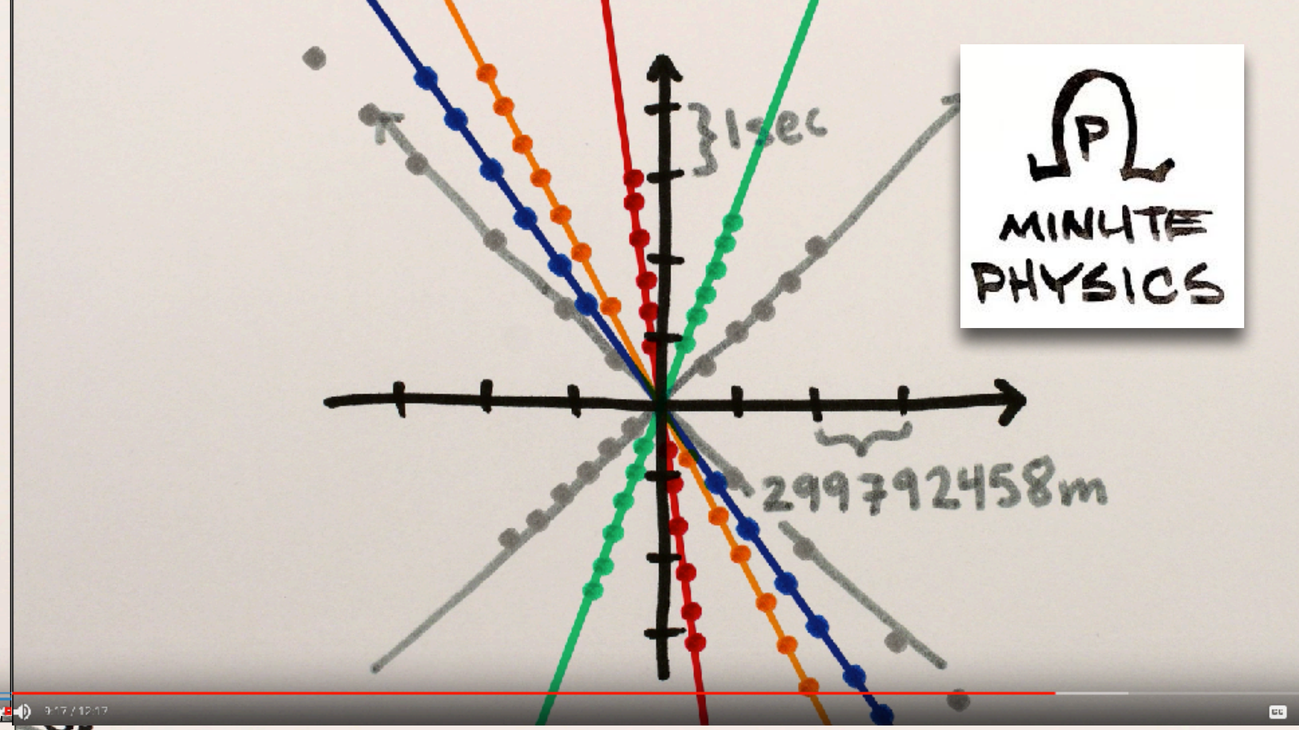
$$\frac{1}{\sqrt{1 - v^2/c^2}},$$

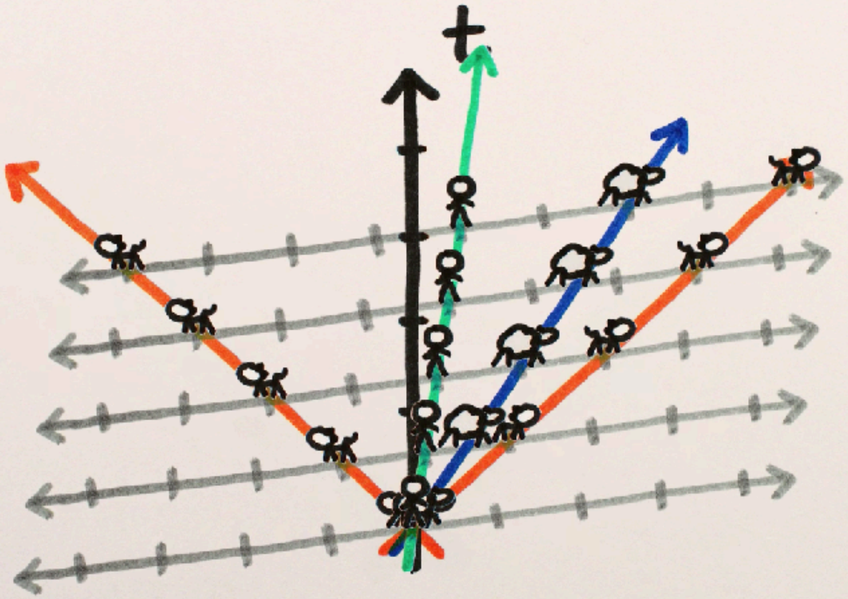
$v^2 / c^2 \approx 0$ for all “normal” velocities,
so this factor is usually ≈ 1

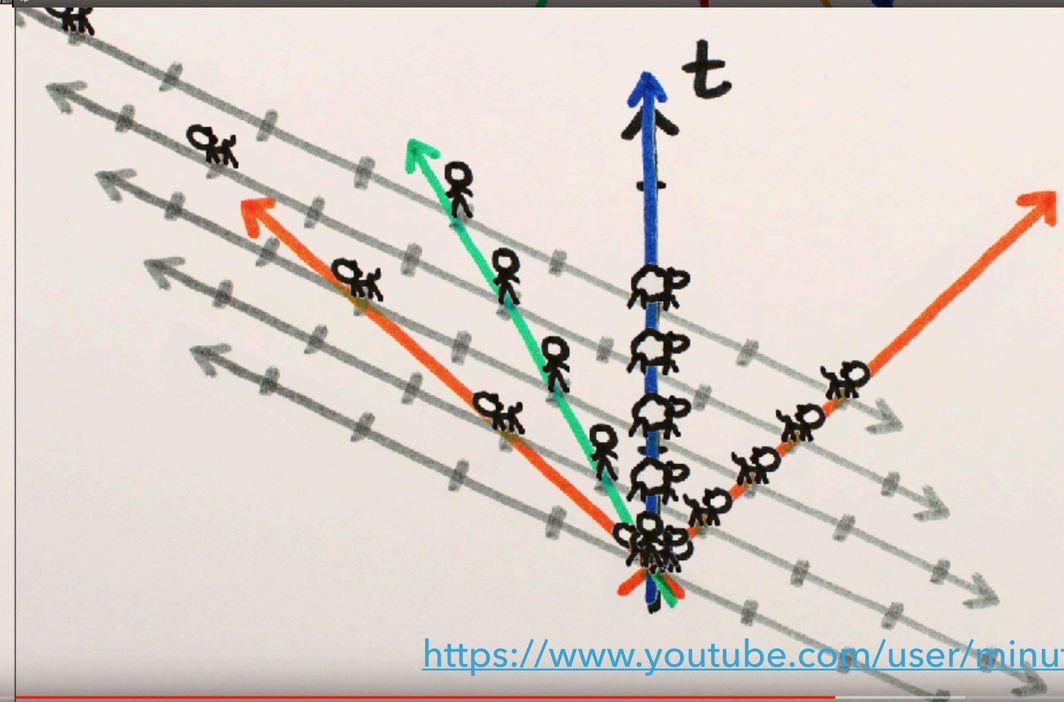

γ
10
9
8
7
6
5
4
3
2
1
0
c / 2
c
v

LORENTZ TRANSFORMATIONS

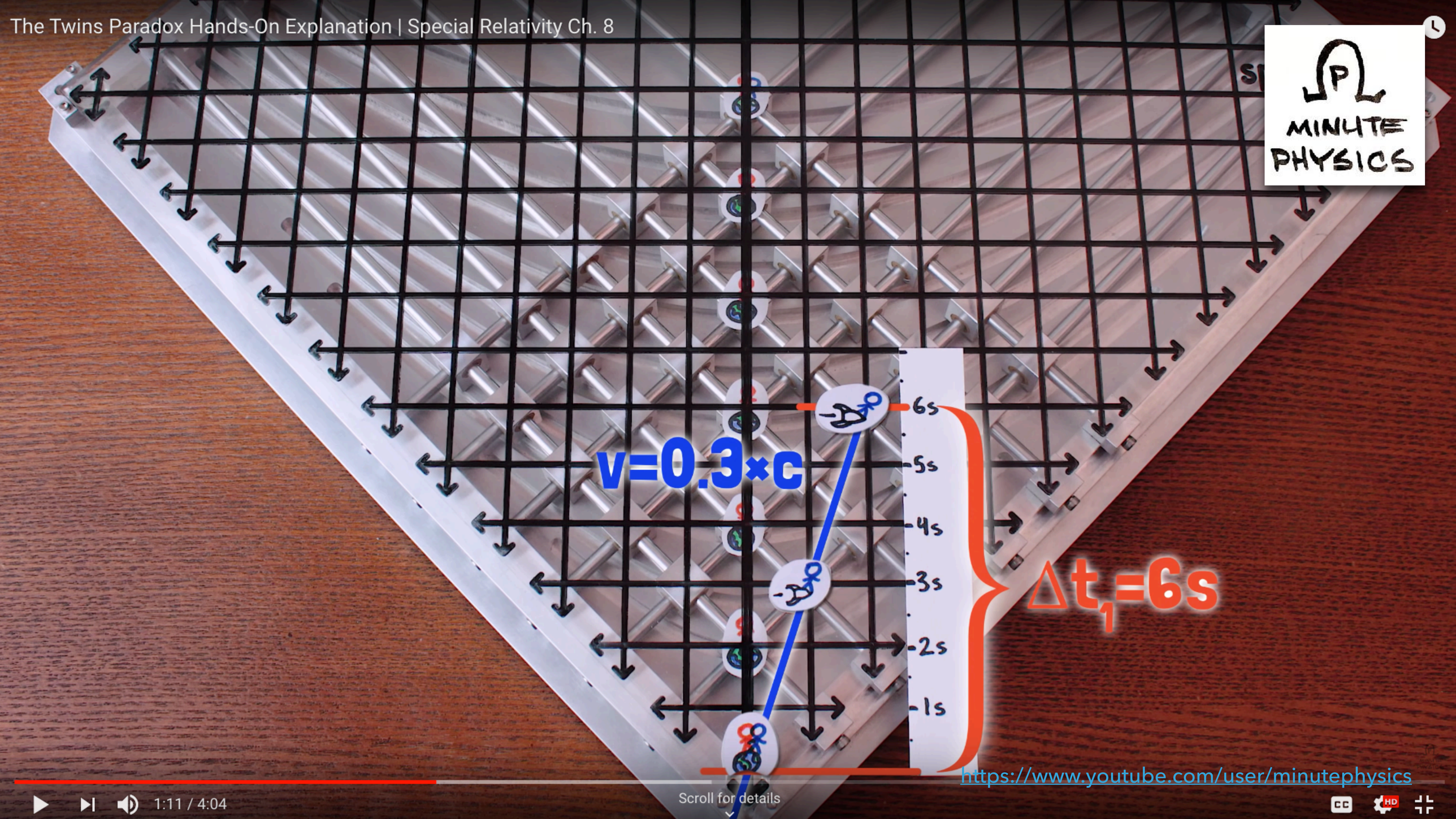






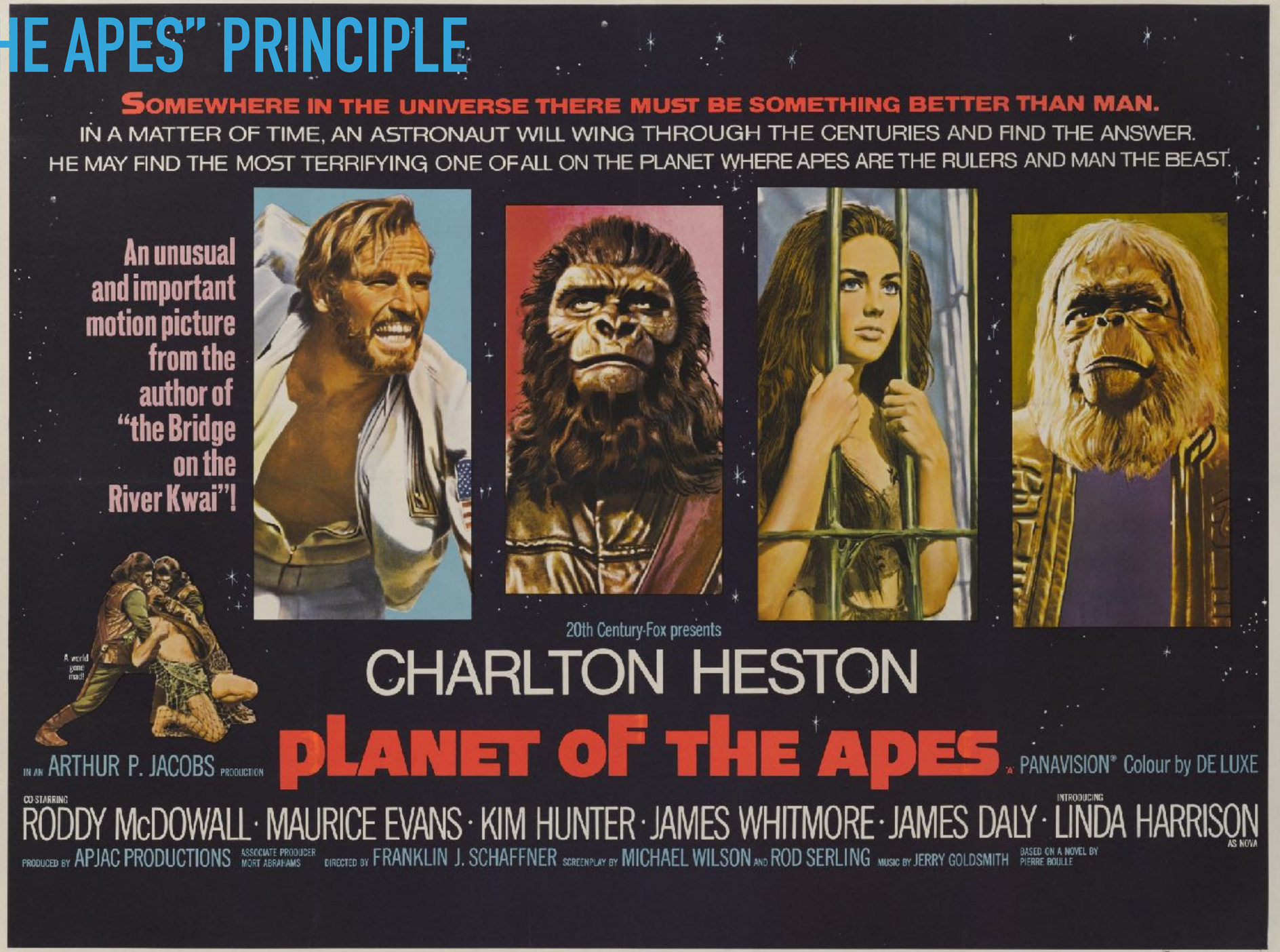


https://www.youtube.com/user/minutephysics


The Twins Paradox Hands-On Explanation | Special Relativity Ch. 8
MINUTE PHYSICS
v=0.3×c
6s
5s
4s
3s
2s
1s
Δt1=6s
https://www.youtube.com/user/minutephysics
1:11 / 4:04
Scroll for details

THE “PLANET OF THE APES” PRINCIPLE

Moving clocks “run slow” compared to a “stationary” clock



THE “PLANET OF THE APES” PRINCIPLE

Moving clocks “run slow” compared to a “stationary” clock

SOMEWHERE IN THE UNIVERSE THERE MUST BE SOMETHING BETTER THAN MAN.

IN A MATTER OF TIME, AN ASTRONAUT WILL WING THROUGH THE CENTURIES AND FIND THE ANSWER.
MAY FIND THE MOST TERRIFYING ONE OF ALL ON THE PLANET WHERE APES ARE THE RULERS AND MAN THE BEAST.

An unusual and important motion picture from the author of “the Bridge on the River Kwai”!

20th Century-Fox presents

CHARLTON HESTON

IN AN ARTHUR P. JACOBS PRODUCTION

PLANET OF THE APES

PANAVISION® Colour by DE LUXE

CO STARRING RODDY McDOWALL · MAURICE EVANS · KIM HUNTER · JAMES WHITMORE · JAMES DALY · INTRODUCING LINDA HARRISON AS NOVA

PRODUCED BY APJAC PRODUCTIONS ASSOCIATE PRODUCER MORT ABRAHAMS DIRECTED BY FRANKLIN J. SCHAFFNER ROD SERLING MUSIC BY JERRY GOLDSMITH BASED ON A NOVEL BY PIERRE BOULLE

Spends 1 year in suspended animation

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INTRODUCING

AS NOVA

PRODUCED BY APJAC PRODUCTIONS ASSOCIATE PRODUCER MORT ABRAHAMS DIRECTED BY FRANKLIN J. SCHAFFNER MICHAEL WILSON AND ROD SERLING MUSIC BY JERRY GOLDSMITH BASED ON A NOVEL BY PIERRE BOULLE

Wakes up in the distant future when apes rule!

THE “INTERSTELLAR” PRINCIPLE

3 hours on
Miller’s Planet

Gravity slows
clocks

IEX SHOEBOX

61km fiber loop adds 350 microseconds

https://iextrading.com/
via Hackaday